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Natural Gas Vehicle Demonstration by Union Gas

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Prepared by:
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Abstract:
During a two-year study priod, a 25-vehicle fleet operated on natural gas to assess the potential cost savings. A 35% fuel cost saving was realized with a two-year average CNG usage of 77% for the dual-fuel (gasoline/natural gas) fleet.

Key Words: Natural gas, demonstration, vehicles, alternative fuels

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TABLE OF CONTENTS

PAGE

1/ INTRODUCTION 1

2/ DATA COLLECTION AND MANIPULATION 2
2.1/ Data Recording. 2
2.2/ Method of Calculations. 3

3/ HAMILTON CNG COMPRESSOR STATION 5
3.1/ General 5
3.2/ Changes and Additions 5
3.3/ Station Operation 6
3.4/ Compressor Operations and Related Problems. 10
3.5/ Compressor Station Noise Analysis 11

4/ CONVERSION INSTALLATION PROBLEMS 12

5/ FUEL ECONOMY 13
5.1/ Fuel Economics -- Natural Gas vs. Gasoline. 13
5.2/ Fuel Economy Data 14

6/ VEHICLE MAINTENANCE COSTS 18

7/ OIL ANALYSIS 21

8/ VEHICLE OPERATION AND MAINTENANCE PROBLEMS 22
8.1/ Freeze-off. 22
8.2/ Stalling. 22
8.3/ Cold Starting 23
8.4/ Power Loss. 23
8.5/ Vehicle Breakdown 24
8.6/ Gas Leaks -- Filters and Tubings. 24
8.7/ Gas Leaks -- Inlet Seals of Regulators. 24
8.8/ Ignition Breakdown. 25
8.9/ Fuel Gauge Malfunction. 25
8.10/ Gas Leaks -- Fill Probe. 25
8.11/ Gas Leaks -- Check Valve 26
8.12/ Discussion 26

9/ CONCLUSION 27

TABLE OF CONTENTS(CONT'D)

APPENDICES

1/ Site Plan
2/ Consumer and Corporate Affairs -- Canada Test Records
3/ Noise Level Studies
4/ Driver's Weekly Fuel Record
5/ Compressor Hydro Costs
6/ Vehicle Maintenance Data
7/ Fuel Economy
8/ Oil Analysis
9/ Vehicle Description
10/ Computer Programs
11/ Ontario Utilities Specifications

EXECUTIVE SUMMARY

During a two-year period from April 1, 1983 to March 31, 1985, the Union Gas Company studied the operation of a 25-vehicle dual-fuel natural gas/gasoline fleet. This report is written by Union Gas and is a summary of the results of this demonstration project.

An electric compressor facility was constructed on site for refuelling of the fleet with compressed natural gas. The facility had both slow- and fast-fill capabilities.

Electrical operating costs of the compressor were tracked and included in fuel cost calculations. Fuel quantity delivered to each vehicle was recorded as accurately as possible to assess vehicle fuel consumption on natural gas.

Vehicle maintenance costs were also monitored to evaluate differences versus gasoline vehicles. Overall, very little difference was detected.

Many operational problems were experienced and resolved, including fuel system freezing due to moisture in the pipeline natural gas, compressor component durability, and vehicle conversion concerns.

Sound level measurements near the refuelling facility showed no appreciable increase in local noise levels during compressor operation.

Engine oil analysis did not detect any abnormal wear in the fleet.

In summary, a significant 35% operating cost saving was experienced compared to gasoline fleet experience during the two-year test period.

1/ INTRODUCTION

The need to achieve energy self-sufficiency by the 1990s is a desirable goal of our society. In an effort to achieve this objective, several projects were initiated by the Ministry of Transportation and Communications to study alternative fuels.

This is the final report regarding a project by Union Gas Limited, which involves a study in the operation of a fleet of 25 vehicles using natural gas (NG) as a motor fuel. It represents a complete summary of the project that was carried out between April 1, 1983 and March 31, 1985.

The initial compression facilities were fast-fill. Slow-fill facilities were added late in the summer of 1983. The fast-fill cascade has since been expanded to a present capacity of over 906 m^3 (32 000 scf).

Twenty-five vehicles of varying make and use were chosen. They range from a four-cylinder passenger car to a 14 515 kg (32 000 lb) GVW dump truck equipped with a V8 engine.

This report presents a detailed summary of station operation, vehicle fuel economy, and conversion and maintenance problems encountered during the two-year study period. All the data collected are provided in appendices, including first and second year data, along with two-year combined data. The significance of these numbers is discussed and explained in the body of the report, and sample calculations have been provided.

2/ DATA COLLECTION AND MANIPULATION

Throughout the two-year study period, extensive data were carefully recorded and organized into tables, provided in the appendices, to allow for easy reference and understanding.

Several methods of collecting and analysing data were employed, and a thorough explanation of each is required so that the reader may fully understand this report.

2.1/ Data Recording

During the first year of the study, April 1, 1983 to March 31, 1984, each driver was issued a "Driver's Weekly Fuel Record," form #2673-1983/03 (Appendix 4), to record distance accumulation data for that vehicle. Throughout this period, all vehicles were filled with natural gas, using fast-fill facilities. All NG dispensed was registered in kilograms by an NG dispenser.

Slow-fill facilities were added late in the summer of 1983, with all vehicles fuelled simultaneously overnight during off-peak electrical hours, preventing long vehicle lineups at the fast-fill dispenser. When using the slow-fill, the NG does not pass through a dispenser, so the kilograms dispensed are not indicated. To account for this, on April 1, 1984, driver form #2673-1983/03 was replaced with form #2673-1983/09 (Appendix 4) on which the driver recorded the natural gas tank pressure when hooking up to the slow-fill and again when disconnecting from it. Using ambient temperatures recorded daily at 8:00 and 17:00 at the Hamilton Airport, the kilograms of NG dispensed were calculated by a computer program (Appendix 10). There were some serious problems associated with this method:

- The pressure gauges used were accurate only to within ± 0.34 MPa (50 psig).
- Hamilton airport is located approximately 20 km from the Strathearne location and the temperature was about 3 to 5°C warmer in the summer and 3 to 5°C cooler in the winter than the temperatures at Strathearne. In addition, the calculation performed to obtain the kilograms of NG requires the NG temperature in the tank before and after the fill and not the ambient air temperature.
- It was also found that, in some cases, these data were being recorded incorrectly or not at all.

To account for the missing data, approximate pressure readings were calculated and substituted, using vehicle-kilometres as a guide.

As a result of these problems, an alternate method of determining the amount of NG dispensed was sought. On December 3, 1984, the fuel factor method was incorporated into the study. Since, in the first year, the kilograms dispensed were indicated directly, accurate fuel data were available for each vehicle; thus, the kilograms of natural gas consumed by each vehicle and the kilometres driven on natural gas were used to determine vehicle fuel factors, as follows:

e.g., Vehicle #762-82 (see Table 7-3-3 in Appendix 7)

km on NG = 28 783 km
kg of NG = 3802.232 kg

$$\text{Fuel Factor} = \frac{3802.232\ \text{kg}}{28\ 783\ \text{km}}$$

$$= 0.13\ \text{kg/km}$$

With an individual fuel factor for each vehicle, the kilograms of natural gas used were determined by multiplying the fuel factor by the number of kilometres driven on natural gas. This method was employed to the end of the study on March 31, 1985.

2.2/ Method of Calculations

The methods of performing calculations on the raw data also changed during the study period. Between April 1, 1983 and September 30, 1983, all calculations were performed manually. This, however, proved to be extremely tedious and time-consuming; therefore, on October 1, 1983, a computer program was incorporated to perform these calculations. This program was employed until March 31, 1984, when the slow-fill facilities were introduced and the mass of natural gas dispensed was no longer registered on a dispenser. To account for this, a computer program, MASS (Appendix 10), was developed to calculate the mass of NG dispensed to a vehicle, based on the temperature and pressure of the gas in the vehicle tank. The equations used (Appendix 10) were derived from Boyle's and Charles' Law, combined with the ideal gas law. At the pressures involved, however, the NG deviates significantly from an ideal gas due to the compressibility of the gas. To account for this deviation, the supercompressibility factor is calculated by the SCFACT program (Appendix 10), which is a subroutine of the MASS program. Both of these programs were written in the IBM computer language APL.

Using the tank pressure before and after the fill, along with the gas temperature and volume, the mass of NG dispensed was determined using these computer programs. In addition, the program was able to compare the calculated mass dispensed to an actual mass dispensed if the vehicle was fuelled using the fast-fill facilities.

The subroutine SFACT calculates the supercompressibility factor for natural gas for the temperature range of -29°C (-20°F) to 93°C (200°F) and the pressure range of 0 MPa (0 psig) to 34.5 MPa (5000 psig). The subroutine was developed using the 1982 company figures for the mole percent of nitrogen and carbon dioxide in the natural gas, along with its specific gravity. When the fuel factor was introduced on December 3, 1984, yet another program was employed.

The fuel economy data have been carefully collected into two yearly reports, which are provided in Appendix 7. In addition, tables containing two-year combined data have been included.

Also contained in these tables are the costs of natural gas, gasoline, and electricity. The natural gas cost is based on the Union Gas M2 residential rate. The electrical costs to run the compressor were calculated from a meter connected to the compressor, which recorded the number of kilowatt-hours used; however, this meter was for Union Gas use only and did not register the demand power. To obtain this number, the demand power of the Strathearne Station before and after the compressor installation, for the same periods, was compared and the difference was used as the compressor demand power. Calculation of the electrical costs are provided in Appendix 5.

3/ HAMILTON CNG COMPRESSOR STATION

3.1/ General

The Hamilton compressed natural gas (CNG) station was installed during the latter part of 1982. The actual test period began on April 1, 1983.

The original equipment installed was a CNG Fuel Systems hydraulic natural gas compressor, Model TR2-20-10-05, with a 50 hp electrical drive. With a suction pressure of 0.69 MPa (100 psig), the three-stage double-acting unit has a capacity of approximately 2.7 m^3/min (97 scfm). For storage, a 20-bottle cascade was installed, which gave a total storage capacity of approximately 283 m^3 (10 000 ft^3).

A CNG Fuel Systems dispenser (Model 2000) was installed to transfer the gas to the vehicles. The measurement is achieved through the use of micromotion mass flowmeters. These meters measure the inertia of the flowing natural gas through a vibrating U tube. A sensor picks up the changes in vibration of the tube and sends a signal to the Kraus computer heads, which do the computations necessary to display the total mass of the vehicle fill, along with the cost.

Appendix 1 illustrates the general layout of the site, including the slow-fill layout, which was installed at a later date.

3.2/ Changes and Additions

The slow-fill addition to the station was completed in October of 1983 and allowed Union's own fleet to have a convenient method of fuelling overnight. Over the last two years, approximately 48% of the total volume of natural gas used by Union's fleet has been dispensed through the slow-fill system.

The slow-fill system consists of a steel pipe barrier with individual fuelling points for each vehicle. This allows the vehicle to be parked in one area, plugged into the fuelling system, and filled overnight.

During the early part of 1984, a methanol injector was added to the high-pressure discharge line to help eliminate freezing problems caused by the high water content of the incoming natural gas. The injector has a variable-rate injection system which will match the water content of the gas with a 50/50 methanol injection.

The storage capacity of the entire system was increased to 906 m^3 (32 000 ft^3) with the addition of two ASME US Steel pressure vessels. These vessels are 6.7 m (22 ft) long and 50.8 cm (20 in) in diameter with a design working pressure of 27.6 MPa (4000 psig).

Along with the increased storage capacity, a sequencing priority fill system was installed to allow optimum utilization of the total storage. The sequencing system splits the total storage into three banks: the first and second banks are the ASME vessels, and the original 20 vessels are the third bank. The priority fill system is computer operated, using the system flow as the sensor. As the flow reduces because of decreased pressure differential, the priority fill system changes to the next highest pressurized storage bank. Based on this premise, the speed of the fill or the amount of storage capacity utilized can be varied.

In preparation for fuelling private vehicles on a self-serve basis, the dispenser and compressor areas were fenced off to isolate them. Also, a computerized fuel management system was installed, which restricted access to authorized users. The system is activated by individual number entry codes. After access is gained, the system will activate the dispenser valves and allow the vehicle to be fuelled. After fuelling is complete, a receipt is printed and made available to the driver. The transactions are also stored for month end reporting and billing by Union Gas.

During the summer of 1984, a gas dryer was installed at the site to test its operation, replacing the methanol injector. The desiccant drying system is a twin-towered, closed-loop, heat-regenerative system. Some delays in installation were encountered during manufacture. Also, obtaining Canadian electrical approval was difficult because the dryer was built in the US. The dew point of the gas is being reduced to a range of -60 to -45°C. The towers will switch for regeneration at approximately -45°C. These dew points translate into a water content of about 0.25 to 0.75 lb/million scf. Freezing problems have not recurred since the dryer has been installed.

3.3/ Station Operation

Table 1 illustrates the utilization of the CNG station during the first two years of operation. The operating hours of the compressor have increased by 28% from the first year to the second to a total of 735 h. This is due to the increased utilization of natural gas as a vehicle fuel by Union Gas, the increased number of vehicles running on NG, and the introduction of sales to private fleets.

Table 1/ Hamilton CNG Station -- Compressor Station Summary

	Year 1 83-03-31 to 84-03-31	Year 2 84-03-31 to 05-03-31	Total
Total Volume Pumped - m^3	78,950	129,360	208,310
Union Fleet Usage - m^3	78,950	120,393	199,343
Private Fleet Usage - m^3	---	8,967	8,967
Electrical Costs	$1,814.43	$2,233.11	$4,047.54
Total Compressor Operating Hours	575 (1)	735	1,310 (1)

NOTE: (1) FIGURE DOES NOT INCLUDE STARTUP HOURS PRIOR TO 83-03-31

1985 05 30

The Union Gas fleet used 78 950 m^3 in the first year of operation. This increased to 120 393 m^3 in the second year.

Sales to private fleets in the Hamilton area began in August of 1984, and volumes have been steadily increasing to a total month's sales of 33 504 m^3 in April of 1985. Table 2 shows the sales growth to the private fleet sector.

The power consumption of the compressor as a dollar value that was actually paid by Union Gas was impossible to discern. This is because the power to the compressor station is fed from the same electrical service as the entire Union Gas Service Centre; the billing as a whole would depend on the total power consumption of the Service Centre. The compressor does, however, have a separate power meter. The numbers presented in Table 1 are based on a separate service and the respective costs for the power consumed by a commercial user in the Hamilton area, as outlined in Appendix 5.

Based on these assumptions, the total value of the power consumed for the two-year period was $4,047. This translates into a cost of $0.0194/m^3 or $0.0187/equivalent litre of gasoline. Again, it should be noted that this cost may be lower if, on the total electrical service, the incremental power consumption of the compressor allows the user to receive greater discounts from the electrical utility because of higher usage or usage during off-peak hours.

Appendix 2 shows the test data from the Consumer and Corporate Affairs Department testing of the dispensers at the station. The micromotion meters have performed favourably and come well within the acceptable tolerance of 2%.

The dispenser was tested each month between October 1983 and February 1984. In almost all cases, the accuracy was within 0.9%. On one occasion, in the month of February, a slow-fill pump test on one pump resulted in a 1.4% error. The reason for this increased error is unknown.

The dispenser was tested again in May of 1985 and the results were well below the 2% tolerance at a maximum error of 0.77%. The dispenser will be tested on a semiannual basis in the future.

Table 2/ Hamilton CNG Station --
Volumes Dispensed to Private Fleets

MONTH	VOLUME (m³)	% INCREASE OVER PREVIOUS MONTH
August 1984	531.3	-
September 1984	535.8	0.8%
October 1984	499.9	(6.7)%
November 1984	793.2	58.7%
December 1984	797.9	0.6%
January 1985	1736.5	117.6%
February 1985	1862.9	7.2%
March 1985	2209.4	18.6%
April 1985	3504.2	58.6%

OVERALL AVERAGE INCREASE - 372 m^3 PER MONTH

1985 05 30

3.4/ Compressor Operations and Related Problems

Several problems were encountered with the CNG hydraulic compressor. The oil seals on all three stages of compression had to be replaced. This problem became apparent when one of the vehicle regulators had to be disassembled and was found full of hydraulic oil.

There were recurring problems with O ring failures and swelling in both the check valves and dome load. The dome load O rings were replaced with a Buna-nitrile rubber "O" ring, which seemed to eliminate the problem. The check valves, however, had continuing problems even with the Buna-N type and were finally replaced with Hoke poppet check valves.

The pressure-limiting switch, which starts the compressor at 22.8 MPa (3300 psig) on the storage system and shuts the compressor down when the pressure reaches 24.8 MPa (3600 psig), had to be replaced because the 2.1 MPa (300 psig) differential (dead band) was inadequate. The short dead band made the compressor start and stop too frequently. A 4.1 MPa (600 psig) dead band switch was installed, eliminating the problem.

Before installation of the priority fill panel, storage pressures of only 23.4 MPa (3400 psig) could be achieved. After the addition of the priority fill panel and a 1.3 cm (0.5 in) sense line to the pressure switch, a final storage pressure of 24.5 MPa (3550 psig) could be achieved. With the total amount of storage on site, the 0.3 MPa (50 psig) of line loss is considered negligible.

After 1258 running hours on the compressor, the Volvo hydraulic pump, which supplies the hydraulic oil to the compression pistons, failed under normal operation. The pump had to be completely rebuilt and upgraded for a higher duty cycle.

The relief valves on the hydraulic system had recurring leaks, likely from faulty O rings. This problem was solved with several replacements of the O rings in the valves.

The display boards on the dispenser were prone to failure and had to be replaced several times. No apparent reason can be given for these failures, but the problem has not recurred recently.

In the early spring of 1985, the coil had to be replaced on the reversing solenoid, the electric switch which changes the flow of hydraulic oil from one end of the cylinder to the other. The vibration and momentum of the reversing action broke the solenoid loose from its mounts.

The frequency of electric power surges and shutdowns in the Strathearne area have caused several failures of the compressor micro control board. Installation of filters on the power lines to reduce the intensity of the power surges seems to have solved the problem.

3.5/ Compressor Station Noise Analysis

Noise level readings were taken on three separate occasions during the afternoon and at midnight. Appendix 3 includes the actual test results.

The first set of readings was taken on September 23, 1982, before the compressor station was fully operable, to establish the baseline levels. The readings ranged from 48 to 52 dBa during the afternoon and 47 to 50 dBa during the night.

On March 3, 1983, the second set of readings was taken. The compressor was fully operational at this time. The afternoon readings were between 48 and 54 dBa, and the midnight readings were between 47 and 56 dBa. The compressor is enclosed in a concrete building; therefore, virtually all sound is contained, with no appreciable increase in noise levels above the baseline. The maximum reading inside the building, while the compressor was running, was 82 dBa.

A third set of readings was taken on May 17, 1984 to verify the results. The afternoon levels were between 48 and 55 dBa, and the evening readings, between 44 and 52 dBa. This substantiated the original conclusion that the station didn't increase the area's normal noise levels.

Because the two readings with the compressor running showed such consistent results and no changes were made to the station that would have increased noise levels, there was no reason to believe the noise levels have changed; thus, no further noise readings have been taken.

4/ CONVERSION INSTALLATION PROBLEMS

The major problem encountered during the conversion process in the fall of 1983 was scheduling the vehicles to be converted. Initially, CNG Fuel Systems indicated a two working-day turnaround time, and vehicles were scheduled accordingly. In fact, this was far from accurate, but in all fairness, it should be noted that the last vehicles that were converted were more in line with the two-day turnaround time. Scheduling delays were caused by the following problems:

- There was an apparent lack of parts for conversion (i.e., tanks, mixers).
- CNG Fuel Systems didn't have enough staff initially to handle the volume of conversions.
- Because varied types of vehicles were converted, many of the mixers had to be manufactured or modified.
- Also, because of the varied type of vehicles, there were some technical setup problems, resuling from a lack of experience on the part of the CNG and Union Gas staff.
- Some technical problems arose because of interpretation and ongoing changes of the CAN1-B149.1-M80 Installation Code (i.e., cylinder shutoff valves and burst disc per bank of cylinders). The vehicles had to be retrofitted with a shutoff valve and burst disc on each cylinder, as well as an under-hood isolation valve.

5/ FUEL ECONOMY

5.1/ Fuel Economics -- Natural Gas vs. Gasoline

The vehicles in this report have been divided into five basic groups for ease of explanation and comparison.

1/ Group A/ Escorts, Cieras, and Laurentians
Although the use of each vehicle may differ, these vehicles are assumed to be similar and will, therefore, constitute an independent study group.

2/ Group B/ Long- and Short-Body Vans
Due to the similar use and engine size of these vehicles, they will constitute a separate study group. Vehicle #375-78 has been omitted from the study due to second-year natural gas data which are obviously incorrect.

3/ Group C/ Utility and Four-Wheel Drive Vehicles
Vehicle #876-79 has an SA200 Lincoln Welder mounted on-board and uses fuel from the same tanks as the vehicle; thus, it will be omitted from the study.

Vehicle #896-78 was designated a spare vehicle shortly after conversion and has travelled few kilometres since conversion; hence, it is not a representative sample and will be excluded from this study.

Vehicles #892-77 and #887-77 have power take-off (PTO)-driven air compressors on-board; thus, their data may also be questionable, but will be included.

4/ Group D/ Ford Rangers
Since these vehicles were converted when they were new, their data will stand alone. It should be noted that their gasoline data were based on past company averages.

5/ Group E/ Ford Dump Truck
Because of the size and use of this vehicle, its data will stand alone in this analysis.

A detailed description of each vehicle is provided in Appendix 9.

5.2/ Fuel Economy Data

Sample calculations for fuel economy are given in Table 3. For ease of comparison, the gasoline and natural gas fuel economy data given in Appendix 7 have been collected into the five vehicle groups and summarized in Table 4.

As can be seen, the cost per kilometre to operate on natural gas was significantly less than the cost per kilometre to operate on gasoline for each vehicle group.

Vehicle Group A, which consisted of five automobiles, achieved savings of 40% in the first year and as high as 55% in the second, for a two-year average of 48%.

Group B, which consisted of long- and short-body vans, experienced a two-year average savings of 31%. During the first year, they managed a 40% savings; however, in the second year, it came down to 21%. Examination of the cost per kilometre to operate on each fuel reveals that this drop did not occur because of a large increase in the cost per kilometre to run on natural gas, but because of better gasoline fuel economy. This drop can be attributed to vehicles #800-77, #814-79, and #885-80. Table 7-2-2 of Appendix 7 shows a large drop in the cost to operate these vehicles. Although the kilometres driven on gasoline did not change significantly, the litres of gasoline used dropped so significantly that the only explanation would be incorrect data; thus, the 20.6% savings in the second year should be considered suspect.

Group C, which consisted of delivery vans, four-wheel drive pickups, and utility vehicles, and which travelled the most kilometres in total, attained savings of 34.4% in the first year and 58.5% in the second for a two-year average of 48%. The jump in savings in the second year can be partially explained by the higher gasoline prices, but mostly by the increased cost per kilometre to operate vehicle #510-80. In the second year, the litres of gasoline used by vehicle #510-80 nearly doubled, whereas the kilometres driven on gasoline remained constant.

Group D, the quarter-ton Ford Ranger pickups, attained a cost per kilometre savings of 65% in the first year and 50% in the second year. This dramatic drop can once again be attributed to the gasoline data. Vehicle #540-83 travelled 1808 km on gasoline and used 651 L in the first year. In the second year, it travelled 2926 km and consumed only 565 L. This would suggest some incorrect data in recording the litres of gasoline used.

Table 3/ Sample Calculations for Fuel Economy Summary

FOR VEHICLE GROUP D - 1st YEAR

GASOLINE

Total \$ to Operate = 240.87 + 218.30 = \$459.17)
)   TABLE 7-2-3
Total Kilometres = 1808 + 1953 = 3761km)

$$\text{Avg. ¢/km} = \frac{459.17}{3761} \times 100 = 12.21\text{¢/km}.$$

NATURAL GAS

Total \$ to Operate = 494.84 + 397.74 = \$892.58)
)   TABLE 7-3-3
Total Kilometres = 12151 + 8408 = 20559km)

$$\text{Avg. ¢/km} = \frac{892.58}{20559} \times 100 = 4.34\text{¢/km}$$

NATURAL GAS vs GASOLINE

Gas btu/km = (5901.78 + 5901.78)/2 = 5901.78)
)   TABLE 7-5-3
NG btu/km = (5172.06 + 6008.92)/2 = 5590.49)

$$\text{btu Ratio} = \frac{5590.49}{5901.78} = 0.95$$

$$\text{\% Savings} = \frac{\text{(Avg. ¢/km) Gas - Avg. ¢/km) NG}}{\text{(Avg. ¢/km) Gas}} \times 100\%$$

$$= \frac{12.21 - 4.34}{12.21} \times 100\%$$

$$= 64.5\%$$

Table 4/ Fuel Economy Summary

	2 YEAR			2nd YEAR			1st YEAR		
GASOLINE									
GRP	TOTAL $ TO OPERATE	TOTAL KILOMETRES	AVERAGE ¢/km	TOTAL $ TO OPERATE	TOTAL KILOMETRES	AVERAGE ¢/km	TOTAL $ TO OPERATE	TOTAL KILOMETRES	AVERAGE ¢/km
A	3,586.49	73,848	4.86	1,799.02	32,882	5.47	1,787.47	40,966	4.36
B	2,113.05	28,542	7.40	705.94	1,091	6.47	1,407.11	17,628	7.98
C	4,178.49	29,342	14.24	2,458.36	14,721	16.69	1,720.13	14,621	11.76
D	840.69	8,090	10.39	381.52	4,329	8.81	459.17	3,761	12.21
E	1,987.11	5,666	35.07	991.44	3,300	30.04	995.67	2,366	42.08
NATURAL GAS									
A	3,872.96	152,585	2.54	1,755.55	71,586	2.45	2,117.37	80,999	2.61
B	7,623.09	149,935	5.08	3,566.88	69,334	5.14	4,056.21	80,601	5.03
C	11,516.77	151,789	7.35	5,043.22	72,883	6.92	6,473.55	83,906	7.72
D	1,695.67	38,928	4.36	803.09	18,369	4.37	892.58	20,559	4.34
E	2,521.30	17,461	14.44	823.39	6,670	12.48	1,688.91	10,791	15.65

NATURAL GAS vs GASOLINE

	2 YEAR				2nd YEAR				1st YEAR			
GRP	GAS btu/km	NG btu/km	btu RATIO	% SVGS	GAS btu/km	NG btu/km	btu RATIO	% SVGS	GAS btu/km	NG btu/km	btu RATIO	% SVGS
A	3783.35	3292.53	.88	47.7	3783.35	3232.13	.86	55.2	3783.35	3352.94	.88	40.1
B	7621.84	6636.71	.88	31.4	7621.84	6594.54	.87	20.6	7621.84	6678.87	.88	36.9
C	12637.06	11418.13	.89	48.4	12637.06	11170.39	.88	58.5	12637.06	11254.91	.89	34.4
D	5901.78	5580.57	.95	58.0	5901.78	5570.64	.94	50.4	5901.78	5590.49	.95	64.5
E	22768.45	17867.99	.78	58.8	22768.45	15852.59	.69	58.5	22768.45	19883.40	.87	62.8

A – Escorts, Cieras, Laurentians
C – Delivery Vans, 4-Wheel Drive Pickups, Utility Vehicles
E – Ford 3 cu.yd. Dump
B – Long and Short Body Vans
D – ¼-Ton Pickup

Group E consisted of only one Ford dump truck, which experienced savings as high as 63% during the first year and 58.3% in the second for a two-year average of 59%.

When the study began in April of 1983, a control group of 25 gasoline-operated vehicles was designated, which would be used to compare to the 25 converted vehicles. However, during the second year, several of these vehicles were also converted, so the control group was dissolved.

The columns titled "Gasoline and Natural Gas Btu's/km" are an indication of the fuel energy used to travel a kilometre and is calculated as shown in Appendix 7. From the ratio of Btu's used per kilometre, it can be seen that less fuel energy is consumed on natural gas than on gasoline. This occurs because natural gas combusts more completely than gasoline, resulting in greater fuel economy and fewer emissions.

Perhaps the most effective summation of these data is the total fuel savings experienced. Over the two-year study period, a total of $25,076 in fuel costs was saved by operating on natural gas. It should be noted, however, that this number was calculated using the price that Union Gas is charged for gasoline. These prices are indicated in Tables 7-2-2 and 7-2-3 of Appendix 7.

6/ VEHICLE MAINTENANCE COSTS

The maintenance costs for the demonstration fleet were carefully recorded and divided into two categories: true maintenance and research- and development-related maintenance. True maintenance costs consist of scheduled service and repairs required to keep the vehicle at our operating standards. Research and development maintenance costs include such items as oil sampling and work that would not normally have been done but was undertaken to better analyse the operation of a vehicle on natural gas.

As mentioned, the control group, which consisted of 25 vehicles similar to the study group but not converted to natural gas, was dissolved after the first year; therefore, a maintenance cost comparison can only be done for that period.

Comparing the maintenance costs of the study group to the control group, as in Table 5, it can be seen that the study group costs (based on a /km value) are higher. If the natural gas maintenance costs are separated out of the study group, it can be seen that the gasoline maintenance costs are higher for some of the vehicle groups in the study group than in the control group.

This inconsistency simply proves that the control group does not represent the study group accurately. It should be noted that the maintenance costs quoted for the control group do not necessarily cover exactly one year. The costs were extracted from vehicle maintenance records. The costs span the approximate period from April 1, 1983 to March 31, 1984 but vary depending on when the individual vehicles were in for maintenance.

As can be seen from Table 5, the cost of maintenance directly attributed to natural gas is relatively low.

In the long run, the maintenance costs will probably not be significantly lower. It is expected that the cost of maintaining a dual-fuel vehicle to be about the same as a gasoline-powered vehicle. This is because the savings in maintaining a natural gas-fuelled vehicle are eroded by the cost of maintaining two fuel delivery systems on one vehicle.

In February of 1985, Vehicle #800-77 developed an engine problem that was not related to the natural gas. The opportunity was taken to remove the engine head and have it inspected for valve recession. Diversified Fuel Components in Windsor, Ontario inspected the head and concluded that there was no evidence of any valve recession after a natural gas utilization of 92% (24 886 km on NG and 2203 km on gasoline).

In general, engine life is expected to increase with the use of natural gas. Oil change intervals have been doubled from every three to every six months, but this may not be the case for vehicles which travel higher annual distances.

Table 5/ Vehicle Maintenance Comparison

Vehicle Number	Study Group Cost	Study Group km	Control Group Cost	Control Group km	Study /km	Control /km
375-78	984.00	7 451	1323.00	70 401	13.2	1.9
380-82	1899.00	26 524	526.00	11 906	7.2	4.4
387-82	2387.00	38 664	1620.00	52 447	6.2	3.1
510-80	2684.00	31 827	2620.00	12 853	8.4	20.4
540-83	1220.00	13 959	673.00	14 439	8.7	4.7
650-80	1750.00	11 286	2309.00	45 980	15.5	5.0
762-82	2233.00	31 108	754.00	56 154	7.2	1.3
773-80	1549.00	10 473	1244.00	8 881	14.8	14.0
778-80	1925.00	6 462	1258.00	7 189	29.8	17.5
779-80	1341.00	10 969	572.00	8 759	12.2	6.5
800-77	1116.00	14 183	680.00	7 566	7.9	9.0
801-83	1106.00	10 361	813.00	13 913	10.7	5.8
814-79	1319.00	10 991	1194.00	11 344	12.0	10.5
817-78	2168.00	10 880	939.00	11 331	19.9	8.3
826-79	1313.00	12 034	2068.00	6 764	10.9	30.6
862-80	633.00	18 608	949.00	29 527	3.4	3.2
867-82	1180.00	27 200	628.00	10 232	4.3	6.1
873-80	941.00	19 588	657.00	19 813	4.8	3.3
876-79	1503.00	5 338	2328.00	6 583	28.2	35.4
880-79	1874.00	13 157	1282.00	3 564	14.2	36.0
885-80	1559.00	13 618	1065.00	23 967	11.4	4.4
887-77	1621.00	11 566	2400.00	13 236	14.0	18.1
892-77	1835.00	7 562	1137.00	8 708	24.3	13.1
896-78	1821.00	2 271	897.00	6 968	80.2	12.9
898-80	1506.00	5 178	2780.00	17 230	29.1	16.1

Vehicle Groups as Defined in Section 5.2, "Fuel Economy Data"
(all vehicles included)

	Study Group Total ($/km)	Study Group NG($/km)	Control Group ($/km)
Group A	6.7	1.6	4.7
Group B	13.8	3.6	11.0
Group C	25.8	6.9	14.5
Group D	9.7	2.8	5.3
Group E	12.3	1.9	35.9

7/ OIL ANALYSIS

Oil samples were taken for analysis from every vehicle every three months -- or 5000 km -- whichever came first.

Appendix 8 gives the odometer reading at each oil change and indicates the reason for the change. During the first year of the study, 83% of the oil changes were carried out as a result of an unusually high bearing wear rate, indicated by the high copper content in the oil samples. This occurred extensively between February 28, 1983 and March 31, 1984.

In September of 1984, Wear Check, who carried out the oil analysis, was notified by Imperial Oil that in February of 1983, they had added between 109 and 120 ppm (parts per million) of copper to the base oil, and thus, the oil sample analysis showed an increase from between 0 and 30 to 150 ppm. Therefore, the report of unusually high bearing wear in the 1984 fiscal MTC Report is erroneous.

As a result of the analysis carried out by Wear Check, it appears that the oil change intervals can be increased to 10 000 km or every six months with natural gas vehicles.

8/ VEHICLE OPERATION AND MAINTENANCE PROBLEMS

Several major problems were experienced with the study group. These are outlined, along with a description of the action taken to alleviate the problem. In addition, the industry status with respect to the problems has been included.

8.1/ Freeze-off

Problem

When operating a vehicle on NG, the pressure must be reduced to atmospheric before the gas is mixed with air and allowed to enter the engine. This large pressure drop results in expansion of the NG, a process that lowers the temperature of the gas. The regulator becomes very cold and any water in the gas will freeze. As a result, NG cannot pass through the regulator, and the fuel supply to the engine is cut off. This problem was experienced early in the study even though the regulators were originally equipped with an electrical heating system.

Action

It was apparent that the situation could be resolved by adequate heating of the regulator to prevent the freeze-off or by adequate drying of the NG. Modification of the regulator to an engine coolant heating system that had a better heat transfer capacity eliminated freeze-off. A need to dry the gas was not apparent with this system; however, if the NG water content is high (greater than approximately 15 lb/million scf), it may be necessary to dry the gas as well. In the industry, the majority of the regulators used have engine coolant heating.

8.2/ Stalling

Problem

During the study, some vehicles experienced a recurring stalling problem at idle or when coming off of the throttle.

Action

This problem was resolved by changing the method of setting up the sensitivity adjustment on the idle circuit. The problem here was one of lack of knowledge rather than design. With a two-stage regulator, this adjustment was extremely sensitive; through experience, however, the mechanics have become accustomed to making this adjustment. Today, the majority of regulators have a three-stage design rather than the two-stage installed in our study group. With the new regulators, the idle circuit is not as sensitive and, therefore, is much easier to set up.

8.3/ Cold Starting

Problem
Difficulty in starting on NG was experienced with some vehicles, especially in cold weather (below -18°C)

Action
Some of the starting problems were corrected by better regulator setup and better driver education. NG is only flammable when mixed with air in the ratio of between 4.5 and 14.5% by volume; thus, if the vehicle is over or under primed, it will not start.

The starting problem still exists on extremely cold winter mornings (below -18°C). It is felt that this is due partially to the poor condition of the vehicle ignition and cranking systems. In addition, poor regulator performance is to blame. In cold weather, the diaphragms tend to harden, thereby not allowing gas to pass into the engine at the required rate. Regulators today have diaphragms made of more suitable materials, and the cold start problem is becoming less predominant in vehicles converted in 1985.

8.4/ Power Loss

Problem
Most of the vehicles used in this study experienced a loss of power on gasoline and/or NG after conversion. (See Table 9-3 in Appendix 9.)

Action
Some of the power loss problems on NG were corrected by changing the air/fuel ratio by adjusting the power screw in the NG dry hose between the regulator and the mixer.

Some vehicles had original regulators that were too small to deliver the required volume of NG. These regulators were replaced or modified for a larger volumetric capacity. It should be noted that 10% power loss is the minimum loss expected when running on NG. This occurs because a minimum of 10% of the intake air is displaced by the NG.

The power loss on gasoline occurs due to the presence of a mixer mounted directly under the carburetor. This mixer restricts the flow of air into the engine, resulting in a loss of power. In the industry today, better mixer designs are available that do not restrict the airflow when the vehicle is operating on gasoline.

8.5/ Vehicle Breakdown

As the study progressed into its second year, vehicle breakdown resulting from poor wiring became a dominant problem. Wiring connections corroded or simply came apart because of vehicle vibration.

Action

This problem was solved by soldering the wire connections and insulating the connections properly. Today, better quality connectors and the generally accepted practice of soldering have helped bring the wiring up to original equipment manufacturer (OEM) standards.

8.6/ Gas Leaks -- Fittings and Tubings

Problem
Gas leaks at various fittings and tubing connections became a problem.

Action
These leaks were repaired and, at the present time, a soap test is carried out at each PM-B inspection (every six months). In this test, a soap solution is sprayed on each connection and any leaks will cause the soap to bubble. The tube connections that were used on the demonstration fleet are no longer used in the industry, and better sealants for the National Pipe Thread (NPT) threads are available. This has reduced the problem of NG leaks significantly on later conversions.

8.7/ Gas Leaks -- Inlet Seals of Regulators

Problem
The inlet seals of the regulators experienced a very short life, resulting in a natural gas leaking problem. This is not caused by the design of the seal, but the design of the inlet itself (only on Renzo Landi Regulator Models SM, M, and SS).

Action
To date, the problem has not been corrected, but it has been resolved by replacing the O ring inlet seal at each PM-B inspection, thereby replacing it before it starts to leak. A new teflon seal is being experimented with and its life has been found to be approximately one year -- twice the original seal's life.

8.8/ Ignition Breakdown

Problem

Some of the vehicles in the study experienced breakdowns of the dual-curve ignition module, which advances the spark for optimal performance on NG.

Action

Some mounting locations of the module allowed water to enter the unit, causing corrosion and shorting. Better locations were found, and the units are now sealed with silicone before installation.

8.9/ Fuel Gauge Malfunction

Problem

Malfunction of the NG fuel gauge was common for the vehicles in the demonstration fleet.

Action

The analog unit was replaced with a rugged gauge that uses sequential light-emitting diode (LED) lights. There are many durable units available on the market today; however, accuracy is still a problem.

8.10/ Gas Leaks -- Fill Probe

Problem

Problems with the fill probe were encountered during and after fuelling, especially during the winter months.

During fuelling, leaks would develop between the fill probe and refuelling block, because the O rings that make the seal become nicked when the probe is inserted into the block.

Action

This problem was helped by champering the female refuelling block, guiding the fill probe into proper alignment, and partially by using O rings made of viton with a 70 durometer hardness.

8.11/ Gas Leaks -- Check Valve

Problem

Another problem experienced during and at the end of the refuelling process was leakage past the check valve in the fuelling block. This back leakage pressurized the seal of the dust plug and made its removal difficult. The leak resulted from small pieces of the fill probe O ring lodging under the seal of the check valve or the ice buildup under the check valve, caused by the large pressure drop across the valve during refuelling.

Action

Although these problems have not been eliminated, better refuelling blocks are available today and a new fill probe with recessed O rings is being experimented with.

8.12/ Discussion

In the demonstration fleet, most of these problems disappeared when the slow-fill operation was installed. The fill probes were replaced with quick-disconnect couplers. The check valve continued to be a problem, but it was not significant because the O ring material from the fill probe was no longer entering the system. The high pressure drop across the valve is eliminated with the slow-fill facilities, so valve freezing is eliminated.

All of these problems resulted in required maintenance to correct or service the problem. Appendix 6 outlines the costs of repairs and maintenance of the problems discussed on a per vehicle basis.

It should be noted that a conversion done today (which would meet the new Ontario Utilities Specifications given in Appendix 11) would not experience the majority of these problems.

9/ CONCLUSION

During the two-year study period from April 1, 1983 to March 31, 1985, natural gas has proven to be an economical and practical alternative to gasoline.

By operating on natural gas with a two-year average utilization of 77%, the 25 vehicle demonstration fleet saved over $25,000 in gasoline cost, a 35% savings. With ever-rising gasoline prices, this savings will continue to increase.

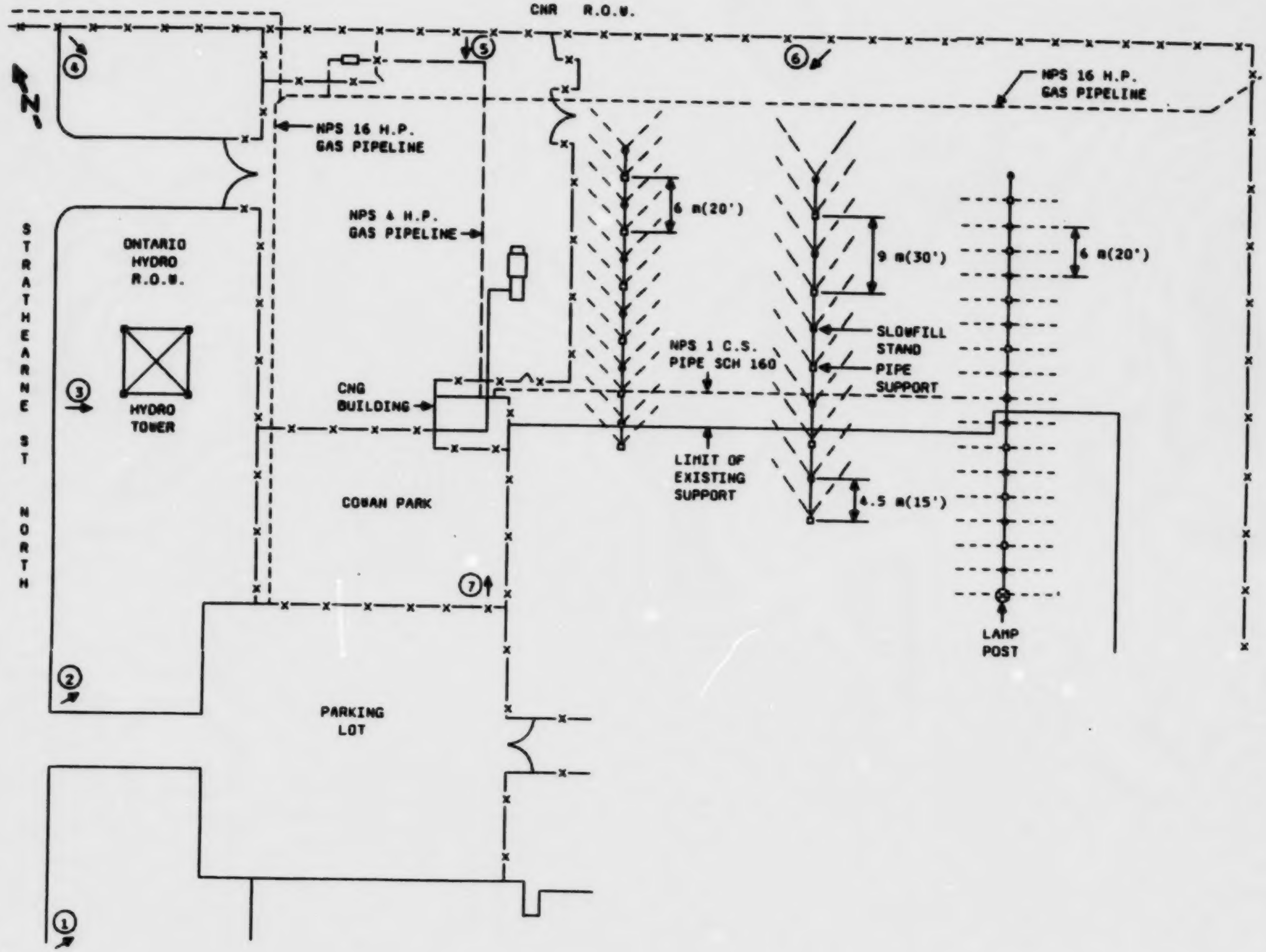
Although several problems were encountered with the compressor operation, most have been solved, and the service time on the unit has been reduced significantly. In addition, a great deal of experience was gained which would eliminate many problems in a similar future installation.

Vehicle maintenance problems have also been brought under control through both experience and better equipment. As was mentioned, recently converted vehicles do not encounter the majority of the problems experienced during this study and, thus, maintenance costs are significantly lower.

Overall, the study went well and the experience has indicated that natural gas has tremendous potential as an alternative vehicle fuel. As gasoline prices escalate and public awareness grows, natural gas will play a significant role as the most attractive and the safest vehicle fuel.

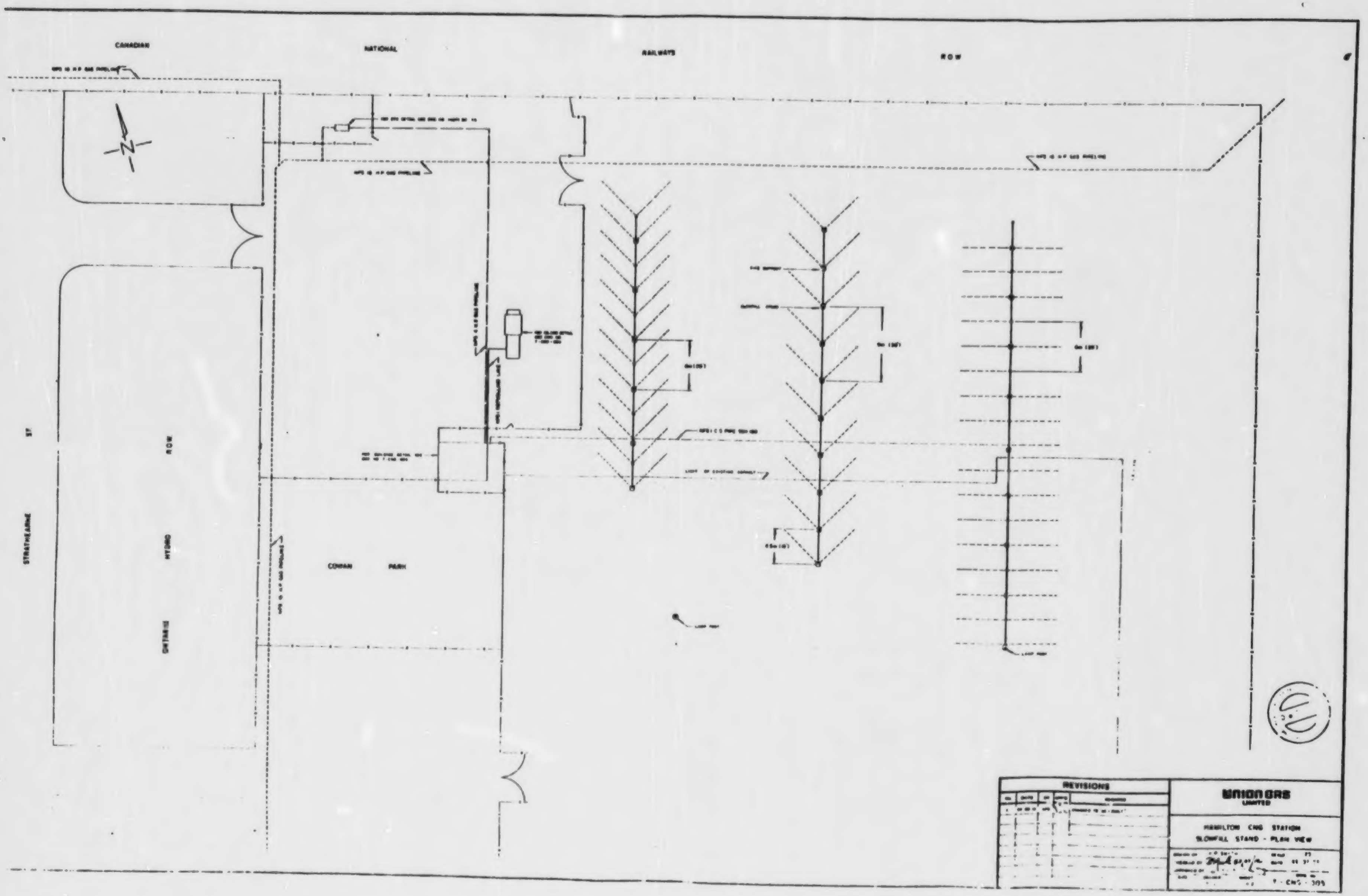
APPENDIX 1

SITE PLAN


CNR R.O.W.
N
④
⑤
⑥
NPS 16 H.P. GAS PIPELINE
NPS 16 H.P. GAS PIPELINE
NPS 4 H.P. GAS PIPELINE
STRATHEARNE ST NORTH
ONTARIO HYDRO R.O.W.
HYDRO TOWER
③
CNG BUILDING
COWAN PARK
⑦
②
PARKING LOT
①
6 m(20')
9 m(30')
6 m(20')
SLOWFILL STAND
PIPE SUPPORT
NPS 1 C.S. PIPE SCH 160
LIMIT OF EXISTING SUPPORT
4.5 m(15')
LAMP POST

APPENDIX 2

CONSUMER AND CORPORATE AFFAIRS - CANADA
TEST RECORDS

CANADIAN
NATIONAL
RAILWAYS
ROW
STRATHEARNE
ST
ONTARIO
HYDRO
ROW
COWAN
PARK
N
REVISIONS
UNION GAS
LIMITED
HAMILTON CNG STATION
SLOWFILL STAND - PLAN VIEW
CNG - 305

Consumer and Corporate Affairs Canada   Consommation et Corporations Canada

Consumer Affairs   Consommation

OR
OR

ROOM / CHAMBRE —

WATER / EAU —

GAS METER FIELD NOTE
(POSITIVE DISPLACEMENT METER)
NOTE D'INSPECTION DE COMPTEURS À GAZ
(COMPTEUR À DÉPLACEMENT POSITIF)

No. 10

DETAILS OF METERS TESTED AT / DÉTAILS DES COMPTEURS VÉRIFIÉS À HAMILTON

PROVER NO. / NO DE L'APPAREIL D'ÉPREUVE

DISTRICT NIAGARA.

FOR THE / POUR CNG FUEL SYSTEMS.

DATE MAY 10, 1985

INSPECTION NO. / NO D'INSPECTION	MAKER / FABRICANT	MAKER'S NO. / NO DU FABRICANT	TYPE / GENRE	CAPACITY / CAPACITÉ: CU. FT. PER HR. / PI. CU. PAR H.	CAPACITY / CAPACITÉ: LIGHTS / LAMPES	CAPACITY / CAPACITÉ: NO.	R.R. OR D. R.T. OU COM. TESTÉ	REJECT / REJETÉ	ERROR / ERREUR: 150%	ERROR / ERREUR: 50%
1.		INSITU TEST RESULTS FOR COMPRESSED NATURAL GAS								
2.		MICRO-MOTION MASS FLOW METER INSTALLATION AT								
3.		UNION GAS CO. STRATHEARNE ST. HAMILTON.								
4.										
5. INST. # ONT-	1001 A	-20033A	VOLUME (KG)			$ REGISTER.				
6.		FULL FLOW.	+0.502%			-0.001				
7.		SLOW FILL.	-0.773%.			-0.001				
8.										
9.										
10. INST. # ONT-	1001B.	-20033A.								
11.		FULL FLOW	+0.631%			-0.002				
12.		SLOW FILL	+0.599%			0.000				
13.										
14.										
15.										
16.										
17.										
18. TEST EQUIPMENT		USED / SCALE #	G-1465							
19.										
20.										

NOTE: INSPECTED MAY 9, 1985 BY MR. RON WILLIS & TED CORLETT

TOTAL

CARDS ENTERED / CARTES ENTRÉES

TESTED BY / ÉPROUVÉS PAR Bob Yau

CERTIFICATE NO. / CERTIFICAT NO.

CLASS	N/R	Insp.	Ver'd	Rej'd	Time

SEAL PERIOD EXPIRES / LA PÉRIODE DU SCEAU EXPIRE

SUMMARY ENTERED / RÉSUMÉ CONSIGNÉ

RECEIVED PAYMENT OF ABOVE FEES / REÇU PAIEMENT DES DROITS CI-DESSUS

DUPLICATE F.N. / DUPLICATA DE N.I. TO / À

RECEIVED BY / REÇU PAR

COMPANY REPRESENTATIVE - REPRÉSENTAN

CCA-686 (5-80)

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

UNION GAS DISPENSER #3
SENSOR CASE SERIAL #20032A

N.G.V. TEST RECORD SHEET

DISTRICT: NIAGARA

DATE: MAY 9 , 1985

INSTALLATION #: 1001 A

LOCATION: UNION GAS - STRATHEARNE

SCALE SERIAL #: G-1468

TEST TANK SERIAL #: N/A

GAS WEIGHT ERROR CALCULATIONS:

	FAST FLOW TEST	SLOW FLOW TEST
A) TEST TANK WEIGHT AFTER FILLING	5.946 kgs	2.348 kgs
B) TEST TANK WEIGHT PRIOR TO FILLING	0.0 kgs	0.0 kgs
C) TRUE WEIGHT OF GAS (A - B)	5.946 kgs	2.348 kgs
D) REGISTERED WEIGHT OF GAS	5.976 kgs	2.330 kgs
E) ERROR (C - D) IN WEIGHT	-0.030 kgs	+0.018 kgs
F) FILLING TIME	270:0 sec	99.0 sec
FIELD NOTE ERROR $\frac{D - C}{D} \times 100$ Tolerance = ± 2.0%	+0.502	-0.773
REGISTER CALCULATION CHECK		
D x Register Price per Kg of 36¢	$ 2.151	$ 0.839
Registered Total Price	$ 2.15	$ 0.84
G) ERROR (Tolerance ± $0.01)	-$ 0.001	-$ 0.001
FULL PRESSURE	~~3000~~ 2800 psi	psi
START PRESSURE	0 psi	1500 psi
GAS TEMPERATURE	—	—

REMARKS:

Ron Willms & TED CORLETT

INSPECTOR'S SIGNATURE

Consumer and Corporate Affairs Canada Consommation et Corporations Canada

UNION GAS DISPENSER #T
SENSOR SERIAL # 20033A

N.G.V. TEST RECORD SHEET

DISTRICT: NIAGARA

DATE: MAY 9, 1985

INSTALLATION #: 1001 B

LOCATION: UNION GAS - STRATHEARNE

SCALE SERIAL #: G-1468

TEST TANK SERIAL #: N/A

GAS WEIGHT ERROR CALCULATIONS:

	FAST FLOW TEST	SLOW FLOW TEST
A) TEST TANK WEIGHT AFTER FILLING	5.831 kgs	1.161 kgs
B) TEST TANK WEIGHT PRIOR TO FILLING	0.0 kgs	0.0 kgs
C) TRUE WEIGHT OF GAS (A - B)	5.831 kgs	1.161 kgs
D) REGISTERED WEIGHT OF GAS	5.868 kgs	1.168 kgs
E) ERROR (C - D) IN WEIGHT	-0.037 kgs	-0.007 kgs
F) FILLING TIME	147.4 sec	105.7 sec
FIELD NOTE ERROR (D - C)/D x 100 Tolerance = ± 2.0%	+0.631	+0.599
REGISTER CALCULATION CHECK D x Register Price per Kg @ 36¢	$ 2.112	$ 0.420
Registered Total Price	$ 2.11	$ 0.42
G) ERROR (Tolerance ± $0.01)	-$ 0.002	$ 0.000
FULL PRESSURE	~~3000~~ 2730 psi	~~3000~~ 2800 psi
START PRESSURE	0 psi	~~1500~~ 1400 psi
GAS TEMPERATURE	—	—

REMARKS:

Ron Willms & TED CORLETT

INSPECTOR'S SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA
DATE 13 Feb /84
INSTALLATION# 1001B
LOCATION UNION GAS STRATHEARNE A[illegible]

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # ______
Test Tank Serial = [illegible]

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.977 kgs	4[illegible].47[illegible] kgs
(B) Test Tank Weight Prior to Filling..	35.339 kgs	37.907 kgs
(C) True Weight of Gas (A - B)........	4.6380 kgs	[illegible]563 kgs
(D) Registered Weight of Gas...........	4.606 kgs	2.[illegible] kgs
(E) Error (C - D) in Weight............	.032 kgs	.0[illegible] kgs
(F) Filling Time.......................	54.3 sec	83 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	-.69%	-.83
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG..........	$ 1.65[illegible]2	$ .9[illegible]
Registered Total Price...............	$ 1.66	$ .92
(G) ERROR (Tolerance $0.01)...........	$ .0018[illegible]	$.[illegible]
Full pressure	2700 psi	2700 psi
Gas temperature		

REMARKS:

Grant Price
INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 13 II / 84

INSTALLATION# 1001A LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

AS 1777

Scale Serial # ______ Test Tank Serial # HA 953

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	40.370 kgs	40.462 kgs
(B) Test Tank Weight Prior to Filling.	35.354 kgs	38.090 kgs
(C) True Weight of Gas (A - B)........	5.016 kgs	2.372 kgs
(D) Registered Weight of Gas..........	5.028 kgs	2.338 kgs
(E) Error (C - D) in Weight..........	.012 kgs	.034 kgs
(F) Filling Time......................	85 sec	78.4 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	+.23	-1.4
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG..........	$ 1.81008	$ .84168
Registered Total Price..............	$ 1.81	$ .8
(G) ERROR (Tolerance $0.01).........	$ .00008	$ .0016
Full pressure	2700 psi	2700 psi
Gas temperature		

REMARKS:

RECEIVED
1984 02 23
TRANSPORTATION DEPT.

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada [illegible]

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE JAN 6 1984

INSTALLATION# 13-1-A LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # SW 560 Test Tank Serial # HA993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.889 kgs	40.056 kgs
(B) Test Tank Weight Prior to Filling..	35.337 kgs	37.540 kgs
(C) True Weight of Gas (A - B)........	4.5520 kgs	2.516 kgs
(D) Registered Weight of Gas..........	4.576 kgs	2.512 kgs
(E) Error (C - D) in Weight...........	.0240 kgs	.004 kgs
(F) Filling Time......................	sec	33 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	+0.52	-0.16
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG.......	$1.6474	$.9043
Registered Total Price............	$1.65	$.90
(G) ERROR (Tolerance $0.01)..........	$.0026	$.0043
Full pressure	2400 psi	2400 psi
Gas temperature		

REMARKS:

Weight Kit 124 M

INSPECTOR's SIGNAT

Consumer and
Corporate Affairs Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE JAN 6 1984

INSTALLATION# 1301 B LOCATION UNION GAS STRATHEARNE AVE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # [illegible] Test Tank Serial # HA 993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.595 kgs	40.050 kgs
(B) Test Tank Weight Prior to Filling..	35.370 kgs	37.822 kgs
(C) True Weight of Gas (A - B)........	4.225 kgs	2.223 kgs
(D) Registered Weight of Gas..........	4.188 kgs	2.218 kgs
(E) Error (C - D) in Weight...........	.0370 kgs	.010 kgs
(F) Filling Time......................	sec	35 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	$\bar{0}.88$	$\bar{0}.45$
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG. 31¢...	$ 1.3078	$.7985
Registered Total Price............	$ 1.51	$ 0.80
(G) ERROR (Tolerance $0.01)..........	$.0023	$.0015
Full pressure	psi	psi
Gas temperature		

REMARKS:

weight [illegible]

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT Niagara

DATE 5 Dec 1983

INSTALLATION# 10313

LOCATION Union Gas Strathearne Av

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # SW 56[illegible]

Test Tank Serial # HA 993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.790 kgs	39.960 kgs
(B) Test Tank Weight Prior to Filling.	35.355 kgs	37.815 kgs
(C) True Weight of Gas (A - B)........	4.435 kgs	2.145 kgs
(D) Registered Weight of Gas..........	4.414 kgs	2.150 kgs
(E) Error (C - D) in Weight...........	.021 kgs	.005 kgs
(F) Filling Time......................	42.5 sec	26.6 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$	-0.48%	+0.23
*Tolerance = + or - 1% (one)		
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG. .36	$1.58904	$.7740
Registered Total Price............	$1.59	$.77
(G) ERROR (Tolerance $0.01)..........	+ $.00096	$.0040
Full pressure	2600 psi	2600 psi
Gas temperature		

REMARKS:

weight kit 122-1
20 kg W4-8 (W1)
10 kg W4-4

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 5 Dec /82

INSTALLATION# 1021A LOCATION Union GAS STRATHEARNE Rd.

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # SW 5634 Test Tank Serial # HA 993

	Full Flow Test		Slow Flow Test	
(A) Test Tank Weight After Filling....	39.870	kgs	39.930	kgs
(B) Test Tank Weight Prior to Filling.	35.440	kgs	37.660	kgs
(C) True Weight of Gas (A - B)........	4.43	kgs	2.270	kgs
(D) Registered Weight of Gas..........	4.456	kgs	2.272	kgs
(E) Error (C - D) in Weight...........	.026	kgs	.002	kgs
(F) Filling Time......................	44.7	sec	29.1	sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	+0.58		+0.09	
REGISTER CALCULATION CHECK:				
D x Registered Price Per KG.......	$ 1.60415		$ .81792	
Registered Total Price............	$ 1.60		$ .82	
(G) ERROR (Tolerance $0.01).........	$ .00416		$ .00208	
Full pressure	2600	psi	2600	psi
Gas temperature				

REMARKS:

Weight ~ 1 1220/
20 kgs 44-8 (41)
10 kg. 44-4

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 7 NOV 1983

INSTALLATION# 1001B LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W 569 M Test Tank Serial # MA993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.560 kgs	39.702 kgs
(B) Test Tank Weight Prior to Filling.	35.360 kgs	37.475 kgs
(C) True Weight of Gas (A - B)........	4.20 kgs	2.2270 kgs
(D) Registered Weight of Gas..........	4.198 kgs	2.216 kgs
(E) Error (C - D) in Weight...........	.002 kgs	.006 kgs
(F) Filling Time......................	33 sec	2013 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	-.048%	-.045
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG.......	$ 1.51128	$.80136
Registered Total Price............	$ 1.51	$ .80
(G) ERROR (Tolerance $0.01).........	$ .00128	$.00136
Full pressure	2500 psi	2500 psi
Gas temperature		

REMARKS:

weight kit	2834
20 kgm	44-3 (9)
20 kgm	44-3 (50)
10 kgm	44-4 (1)

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 7 NOV/83

INSTALLATION# 1221A LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W5GAM Test Tank Serial # HR993

	Full Flow Test		Slow Flow Test	
(A) Test Tank Weight After Filling....	39.720	kgs	39.737	kgs
(B) Test Tank Weight Prior to Filling.	35.355	kgs	37.760	kgs
(C) True Weight of Gas (A - B)........	4.365	kgs	1.977	kgs
(D) Registered Weight of Gas..........	4.384	kgs	1.990	kgs
(E) Error (C - D) in Weight...........	.019	kgs	.013	kgs
(F) Filling Time......................	36.0	sec	17.5	sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	+0.43		+.65	
REGISTER CALCULATION CHECK:				
D x Registered Price Per KG.......	$ 1.57824		$ .7164	
Registered Total Price............	$ 1.58		$ .72	
(G) ERROR (Tolerance $0.01)...........	$ .00176		$ .0036	
Full pressure	2500	psi	2500	psi
Gas temperature				

REMARKS:

Weight kit 283 7
20 kgm 44-3 (9)
20 kgm 44-3 (50)
10 kgm 44-4 1

G Price
INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada   Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA   DATE Oct 14 /83

INSTALLATION# 1771 B   LOCATION Union Gas S[illegible]

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W 557   Test Tank Serial #

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.502 kgs	39.780 kgs
(B) Test Tank Weight Prior to Filling.	35.349 kgs	37.454 kgs
(C) True Weight of Gas (A - B)........	4.153 kgs	2.326 kgs
(D) Registered Weight of Gas..........	4.146 kgs	2.336 kgs
(E) Error (C - D) in Weight...........	.007 kgs	.010 kgs
(F) Filling Time......................	35.7 sec	25.7 sec
FIELD NOTE ERROR: $\frac{D-C}{D}$ x 100 *Tolerance = + or - 1% (one)	-.16%	+.43%
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG. .36 ...	$ 1.4926	$ .841
Registered Total Price............	$ 1.49	$ .84
(G) ERROR (Tolerance $0.01).........	$ .0026	$ .001
Full pressure	2500 psi	2500 psi
Gas temperature		

REMARKS:

weigt kit 123 M   20 kgs 44-1 - 41

20 kgs 44-1 - 38

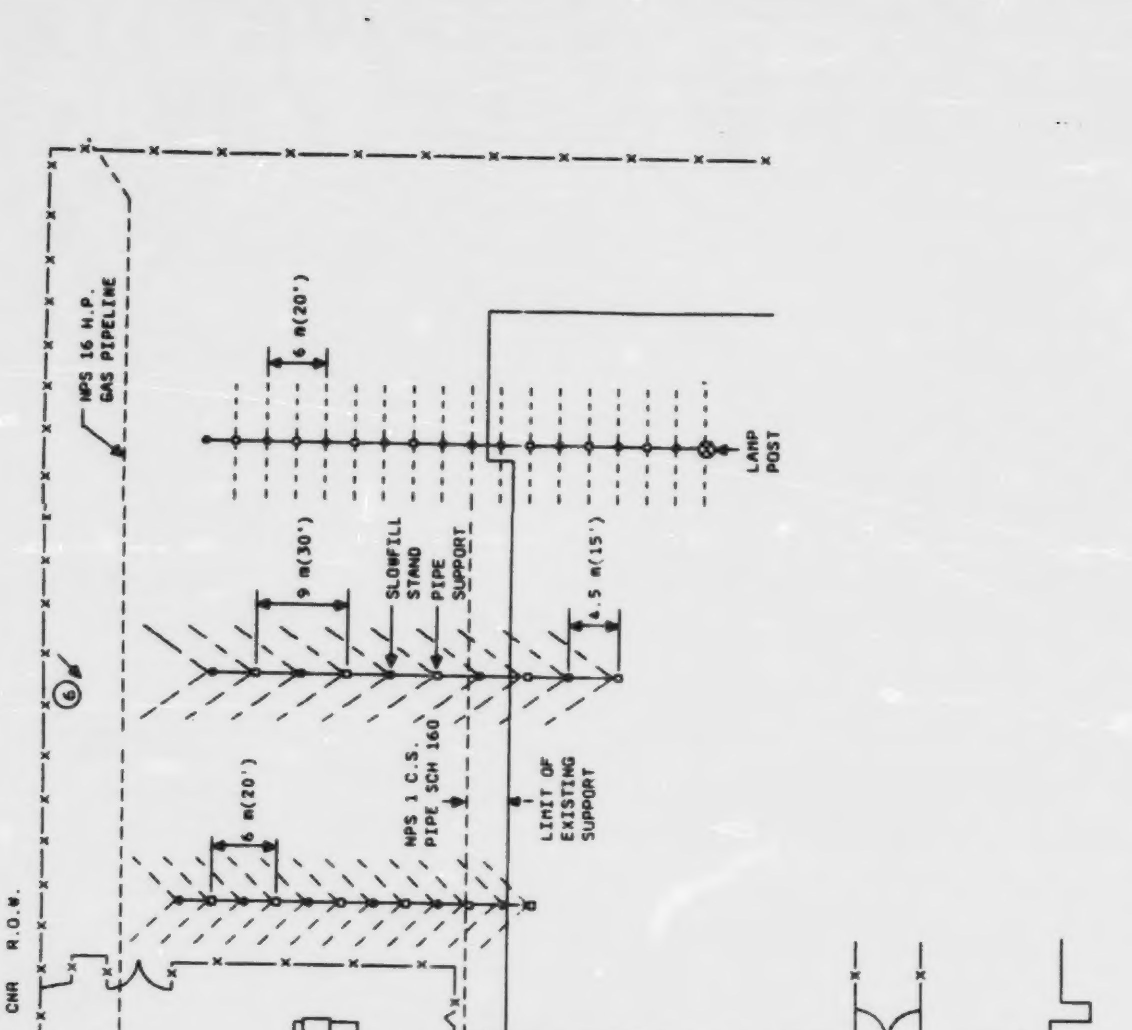
10 kgs 44-14 - 14

FN 101636

G Puro

INSPECTOR's SIGNATURE

SITE PLAN


CNR R.O.W.
NPS 16 H.P. GAS PIPELINE
NPS 16 H.P. GAS PIPELINE
6 m(20')
6 m(20')
9 m(30')
4.5 m(15')
SLOWFILL STAND PIPE SUPPORT
LAMP POST
NPS 1 C.S. PIPE SCH 160
LIMIT OF EXISTING SUPPORT
NPS 4 H.P. GAS PIPELINE
CNG BUILDING
COWAN PARK
PARKING LOT
ONTARIO HYDRO R.O.W.
HYDRO TOWER
STRATHEARNE ST NORTH
N
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APPENDIX 2

CONSUMER AND CORPORATE AFFAIRS - CANADA
TEST RECORDS

Consumer and Corporate Affairs Canada — Consommation et Corporations Canada

Consumer Affairs — Consommation

ORIGIN
ORIGIN

ROOM / CHAMBRE —
WATER / EAU —

GAS METER FIELD NOTE

(POSITIVE DISPLACEMENT METER)

NOTE D'INSPECTION DE COMPTEURS À GAZ

(COMPTEUR À DÉPLACEMENT POSITIF)

No. 1012

DETAILS OF METERS TESTED AT / DÉTAILS DES COMPTEURS VÉRIFIÉS À HAMILTON

PROVER NO. / NO DE L'APPAREIL D'ÉPREUVE

DISTRICT NIAGARA.

FOR THE / POUR CNG FUEL SYSTEMS.

DATE MAY 10, 1985

INSPECTION NO. / NO D'INSPECTION	MAKER / FABRICANT	MAKER'S NO. / NO DU FABRICANT	TYPE / GENRE	CAPACITY / CAPACITÉ: CU. FT. PER HR. / PI. CU. PAR H.	LIGHTS / LAMPES	NO.	N.R. OR D. / N.T. OU CON. TESTÉ	REJECT / REJETÉ	ERROR / ERREUR: 150%	50%
1.		INSITU TEST RESULTS FOR COMPRESSED NATURAL GAS								
2.		MICRO-MOTION MASS FLOW METRE INSTALLATION AT								
3.		UNION GAS CO. STRATHEARNE ST. HAMILTON.								
4.										
5. INST. # ONT-	1001A	-20033A	VOLUME (KG)			$ REGISTER.				
6.		FULL FLOW.	+0.502%			-0.001				
7.		SLOW FILL.	-0.773%.			-0.001				
8.										
9.										
10. INST. # ONT-	1001B.	-20033A.								
11.		FULL FLOW	+0.631%			-0.002				
12.		SLOW FILL	+0.599%			0.000				
13.										
14.										
15.										
16.										
17.										
18. TEST EQUIPMENT		USED 1 SCALE #	G-1468							
19.										
20.										

NOTE: INSPECTED MAY 9, 1985 BY MR. RON WILLIS & TED CORLETT

TOTAL

CARDS ENTERED / CARTES ENTRÉES

CERTIFICATE NO. / CERTIFICAT NO.

CLASS	N/R	Insp.	Ver'd	Rej'd	Time
				TO / À	

SUMMARY ENTERED / RÉSUMÉ CONSIGNÉ

DUPLICATE F.N. / DUPLICATA DE N.I.

TESTED BY / ÉPROUVÉS PAR Bob Young

INSPECTOR

SEAL PERIOD EXPIRES / LA PÉRIODE DU SCEAU EXPIRE

RECEIVED PAYMENT OF ABOVE FEES / REÇU PAIEMENT DES DROITS CI-DESSUS

RECEIVED BY / REÇU PAR

COMPANY REPRESENTATIVE - REPRÉSENTANT DE L

CCA-686 (5-80)

Consumer and Corporate Affairs Canada / Consommation et Corporations Canada

UNION GAS DISPENSER #3
SENSOR CASE SERIAL # 20032A

N.G.V. TEST RECORD SHEET

DISTRICT: NIAGARA DATE: MAY 9, 1985

INSTALLATION #: 1001 A LOCATION: UNION GAS - STRATHEARNE

SCALE SERIAL #: G-1468 TEST TANK SERIAL #: N/A

GAS WEIGHT ERROR CALCULATIONS:

	FAST FLOW TEST	SLOW FLOW TEST
A) TEST TANK WEIGHT AFTER FILLING	5.946 kgs	2.348 kgs
B) TEST TANK WEIGHT PRIOR TO FILLING	0.0 kgs	0.0 kgs
C) TRUE WEIGHT OF GAS (A - B)	5.946 kgs	2.348 kgs
D) REGISTERED WEIGHT OF GAS	5.976 kgs	2.330 kgs
E) ERROR (C - D) IN WEIGHT	-0.030 kgs	+0.018 kgs
F) FILLING TIME	270.0 sec	99.0 sec
FIELD NOTE ERROR $\frac{D - C}{D} \times 100$ Tolerance = ± 2.0%	+0.502	-0.773
REGISTER CALCULATION CHECK		
D x Register Price per Kg of 36¢	$ 2.151	$ 0.839
Registered Total Price	$ 2.15	$ 0.84
G) ERROR (Tolerance ± $0.01)	-$ 0.001	-$ 0.001
FULL PRESSURE	~~3000~~ 2800 psi	~~3000~~ psi
START PRESSURE	0 psi	1500 psi
GAS TEMPERATURE	—	—

REMARKS:

Ron Willms & TED CORLETT

INSPECTOR'S SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

UNION GAS DISPENSER #7
SENSOR SERIAL # 20033A

N.G.V. TEST RECORD SHEET

DISTRICT: NIAGARA DATE: MAY 9, 1985

INSTALLATION #: 1001 B LOCATION: UNION GAS - STRATHEARNE

SCALE SERIAL #: G-1468 TEST TANK SERIAL #: N/A

GAS WEIGHT ERROR CALCULATIONS:

	FAST FLOW TEST	SLOW FLOW TEST
A) TEST TANK WEIGHT AFTER FILLING	5.831 kgs	1.161 kgs
B) TEST TANK WEIGHT PRIOR TO FILLING	0.0 kgs	0.0 kgs
C) TRUE WEIGHT OF GAS (A - B)	5.831 kgs	1.161 kgs
D) REGISTERED WEIGHT OF GAS	5.868 kgs	1.168 kgs
E) ERROR (C - D) IN WEIGHT	-0.037 kgs	-0.007 kgs
F) FILLING TIME	147.4 sec	105.7 sec
FIELD NOTE ERROR $\frac{D - C}{D} \times 100$ Tolerance = ± 2.0%	+0.631	+0.599
REGISTER CALCULATION CHECK		
D x Register Price per Kg @ 36¢	$ 2.112	$ 0.420
Registered Total Price	$ 2.11	$ 0.42
G) ERROR (Tolerance ± $0.01)	-$ 0.002	$ 0.000
FULL PRESSURE	~~3000~~ 2730 psi	~~3000~~ 2800 psi
START PRESSURE	0 psi	~~1500~~ 1400 psi
GAS TEMPERATURE	—	—

REMARKS:

Ron Willms & TED CORLETT

INSPECTOR'S SIGNATURE

Consumer and Corporate Affairs Canada
[illegible]

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA

DATE 13 Feb /84

INSTALLATION# 1001B LOCATION UNION GAS STRATHEARNE AV

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # ____

Test Tank Serial # [illegible]

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.977 kgs	40.470 kgs
(B) Test Tank Weight Prior to Filling..	35.339 kgs	37.907 kgs
(C) True Weight of Gas (A - B)........	4.6380 kgs	2563 kgs
(D) Registered Weight of Gas..........	4.606 kgs	2.[illegible] kgs
(E) Error (C - D) in Weight...........	.032 kgs	.0[illegible] kgs
(F) Filling Time......................	54.3 sec	83 sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ x 100 *Tolerance = + or - 1% (one)	-.69%	-.83
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG........	$ 1.6[illegible]2	$ .9[illegible]
Registered Total Price............	$ 1.66	$ .92
(G) ERROR (Tolerance $0.01)........	$ .0018[illegible]	$.[illegible]
Full pressure	2700 psi	2700 psi
Gas temperature		

REMARKS:

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada · Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 17 II / 84

INSTALLATION# 1001A LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

AS1777

Scale Serial # ______ Test Tank Serial # HA 953

	Full Flow Test		Slow Flow Test	
(A) Test Tank Weight After Filling....	40.370	kgs	40.462	kgs
(B) Test Tank Weight Prior to Filling.	35.354	kgs	38.090	kgs
(C) True Weight of Gas (A - B)........	5.016	kgs	2.372	kgs
(D) Registered Weight of Gas..........	5.028	kgs	2.338	kgs
(E) Error (C - D) in Weight...........	.012	kgs	.034	kgs
(F) Filling Time......................	85	sec	78.4	sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ x 100 *Tolerance = + or - 1% (one)	+.23		-1.4	
REGISTER CALCULATION CHECK:				
D x Registered Price Per KG.......	$ 1.81008		$ .84165	
Registered Total Price............	$ 1.81008		$ .8	
(G) ERROR (Tolerance $0.01)...........	$ .00008		$ .0016	
Full pressure	2700	psi	2700	psi
Gas temperature				

REMARKS:

RECEIVED
1984 02 23
TRANSPORTATION DEPT.

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada [illegible]

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE: JAN 6 198[illegible]

INSTALLATION# 13-1-A LOCATION: UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial #: SW 560 Test Tank Serial # HA993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.889 kgs	40.056 kgs
(B) Test Tank Weight Prior to Filling.	35.337 kgs	37.540 kgs
(C) True Weight of Gas (A - B)........	4.5520 kgs	2.516 kgs
(D) Registered Weight of Gas.........	4.576 kgs	2.512 kgs
(E) Error (C - D) in Weight..........	.0240 kgs	.004 kgs
(F) Filling Time......................	sec	33 sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ x 100 *Tolerance = + or - 1% (one)	+0.52	-0.16
REGISTER CALCULATION CHECK: D x Registered Price Per KG.......	$ 1.6474	$ .9043
Registered Total Price............	$ 1.65	$ .90
(G) ERROR (Tolerance $0.01).........	$ .0026	$ .0043
Full pressure	2400 psi	2400 psi
Gas temperature		

REMARKS:

Weight Kit 12-1 H

INSPECTOR's SIGNAT

2 ✓

Consumer and Corporate Affairs Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA

DATE JAN 6 1984

INSTALLATION# 1301 B LOCATION: UNION GAS STRATHEARNE A/C

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # [illegible]

Test Tank Serial # HA993

	Full Flow Test		Slow Flow Test	
(A) Test Tank Weight After Filling	39.595	kgs	40.050	kgs
(B) Test Tank Weight Prior to Filling	35.370	kgs	37.822	kgs
(C) True Weight of Gas (A - B)	4.225	kgs	2.223	kgs
(D) Registered Weight of Gas	4.188	kgs	2.218	kgs
(E) Error (C - D) in Weight	.0370	kgs	.010	kgs
(F) Filling Time		sec	35	sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ X 100 *Tolerance = + or - 1% (one)	$\bar{0}$.88		$\bar{0}$.45	
REGISTER CALCULATION CHECK:				
D x Registered Price Per KG. 36	$ 1.5078		$.7985	
Registered Total Price	$ 1.51		$0.80	
(G) ERROR (Tolerance $0.01)	$.0023		$.0015	
Full pressure		psi		psi
[illegible] Gas temperature				

REMARKS:

weight [illegible] 121 M

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA
DATE 5 Dec 1983
INSTALLATION# 10313
LOCATION Union Gas Strathearne Av

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # Sw 56[illegible]
Test Tank Serial # HA 993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.790 kgs	39.960 kgs
(B) Test Tank Weight Prior to Filling.	35.355 kgs	37.815 kgs
(C) True Weight of Gas (A - B).......	4.435 kgs	2.145 kgs
(D) Registered Weight of Gas..........	4.414 kgs	2.150 kgs
(E) Error (C - D) in Weight...........	.021 kgs	.005 kgs
(F) Filling Time......................	42.5 sec	26.6 sec
FIELD NOTE ERROR: $\frac{D-C}{D} \times 100$	-0.48%	+0.23
*Tolerance = + or - 1% (one)		
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG. .36...	$1.58904	$.7740
Registered Total Price............	$1.59	$.77
(G) ERROR (Tolerance $0.01).........	+ $.00096	$.0040
Full pressure	2600 psi	2600 psi
Gas temperature		

REMARKS:

weight K.1 122-1
20 kg W4-8 (x1)
10 kg W4-4

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 5 Dec /82

INSTALLATION# 1021A LOCATION UNION GAS STRATHEARNE AV.

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # SW 369 M Test Tank Serial # HA 993

	Full Flow Test		Slow Flow Test	
(A) Test Tank Weight After Filling....	39.870	kgs	39.930	kgs
(B) Test Tank Weight Prior to Filling.	35.470	kgs	37.660	kgs
(C) True Weight of Gas (A - B)........	4.43	kgs	2.270	kgs
(D) Registered Weight of Gas..........	4.456	kgs	2.272	kgs
(E) Error (C - D) in Weight...........	.026	kgs	.002	kgs
(F) Filling Time......................	44.7	sec	29.1	sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ x 100 *Tolerance = + or - 1% (one)	+0.58		+0.09	
REGISTER CALCULATION CHECK:				
D x Registered Price Per KG.......	$ 1.60415		$.81792	
Registered Total Price............	$ 1.60		$ .82	
(G) ERROR (Tolerance $0.01).........	$.00416		$.00208	
Full pressure	2600	psi	2600	psi
Gas temperature				

REMARKS:

Weight #1 1220
20 kgs 44-8 (41)
10 kg. 44-4

G Pirie
INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA

DATE 7 NOV 1983

INSTALLATION# 1001B LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W 560 H

Test Tank Serial # HA993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.560 kgs	39.702 kgs
(B) Test Tank Weight Prior to Filling.	35.360 kgs	37.475 kgs
(C) True Weight of Gas (A - B)........	4.20 kgs	2.2270 kgs
(D) Registered Weight of Gas..........	4.198 kgs	2.221 kgs
(E) Error (C - D) in Weight...........	.002 kgs	.006 kgs
(F) Filling Time......................	33 sec	2013 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$	-.048%	-.045
*Tolerance = + or - 1% (one)		
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG.......	$ 1.51128	$ .80136
Registered Total Price............	$ 1.51	$ .80
(G) ERROR (Tolerance $0.01).........	$ .00128	$ .00136
Full pressure	2500 psi	2500 psi
Gas temperature		

REMARKS:

weight kit	2834
20 kgs	44-3 (9)
20 kgs	44-3 (50)
10 kgs	44-4 (1)

G. Pirie

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE 7 NOV/83

INSTALLATION# 1221A LOCATION UNION GAS STRATHGARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W 5G0 M Test Tank Serial # HR993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.720 kgs	39.737 kgs
(B) Test Tank Weight Prior to Filling.	35.355 kgs	37.760 kgs
(C) True Weight of Gas (A - B)........	4.365 kgs	1.977 kgs
(D) Registered Weight of Gas..........	4.384 kgs	1.990 kgs
(E) Error (C - D) in Weight...........	.019 kgs	.013 kgs
(F) Filling Time......................	36.0 sec	17.5 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	+0.43	+.65
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG.......	$ 1.57824	$ .71640
Registered Total Price............	$ 1.58	$ .72
(G) ERROR (Tolerance $0.01)...........	$ .00176	$ .0036
Full pressure	2500 psi	2500 psi
Gas temperature		

REMARKS:

Weight kit 283 7
20 kgm 44-3 (9)
20 kgm 44-3 (50)
10 kgm 44-4 1

G Price
INSPECTOR'S SIGNATURE

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA
DATE Oct 14 /83

INSTALLATION# 1771B
LOCATION Union Gas [illegible]

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W557
Test Tank Serial #

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.502 kgs	39.780 kgs
(B) Test Tank Weight Prior to Filling.	35.349 kgs	37.454 kgs
(C) True Weight of Gas (A - B)........	4.153 kgs	2.326 kgs
(D) Registered Weight of Gas..........	4.146 kgs	2.336 kgs
(E) Error (C - D) in Weight...........	.007 kgs	.010 kgs
(F) Filling Time......................	35.7 sec	15.7 sec
FIELD NOTE ERROR: $\frac{D - C}{D} \times 100$ *Tolerance = + or - 1% (one)	-.16%	+.43%
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG. .36....	$ 1.4926	$ .841
Registered Total Price...........	$ 1.49	$ .84
(G) ERROR (Tolerance $0.01).........	$ .0026	$ .001
Full pressure	2500 psi	2500 psi
Gas temperature		

REMARKS:

weight kit 123 M 20 kgm 44-1-41
20 kgm 44-1-38
10 kgm 44-14-14

FN 101636

INSPECTOR's SIGNATURE

Consumer and Corporate Affairs Canada - Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE Oct 14 1983

INSTALLATION# 1001A LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # [illegible]557 Test Tank Serial # HA 993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.695 kgs	39.817 kgs
(B) Test Tank Weight Prior to Filling.	35.335 kgs	36.074 kgs
(C) True Weight of Gas (A - B)........	4.360 kgs	2.843 kgs
(D) Registered Weight of Gas..........	4.382 kgs	2.850 kgs
(E) Error (C - D) in Weight...........	0.022 kgs	.007 kgs
(F) Filling Time......................	37.5 sec	31.0 sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ X 100 $\frac{4.382-4.360}{4.382}$ $\frac{2.850-}{2.850}$ *Tolerance = + or - 1% (one)	+0.5%	+0.25%
REGISTER CALCULATION CHECK:		
D x Registered Price Per KG..........	$1.5775	$1.026
Registered Total Price............	$1.58	$1.03
(G) ERROR (Tolerance $0.01)..........	$.0025	$.004
Full pressure	2600 psi	2600 psi
Gas temperature		

REMARKS:

Weight kit 123M 20kgm 44-1 41

20kgm 44-1 37

10kgm 44-14 14

FN 101636

INSPECTOR'S SIGNATURE

APPENDIX 3

NOISE LEVEL STUDIES

W0176-2/78 **MEMORANDUM**

TO: D. B. Davis **DEPT/OFFICE:** Head **DATE:** 1984 05 24

FROM: R. R. Adams **DEPT/OFFICE:** Head

RE: Hamilton NGV Compressor Station Noise Level

Noise levels were measured at the Hamilton Service Centre on Thursday, May 17, 1984 in the afternoon and at midnight. These times were selected to correspond to those used by B. K. Mark and D. I. Harrison in previous studies. The locations selected were those from the previous study by B. K. Mark.

The values observed ranged from 48 to 55 dba in the afternoon and from 44 to 52 dba at midnight. The background noise is listed on the data sheet. The stroking was hardly audible in the afternoon but with the lower background noise at midnight, the stroking of the compressor was audible from all locations. The level inside the building was 86 dba.

As outlined by B. K. Mark in his memo to you (83 03 16) the station clearly meets the Occupational Health and Safety Act, 1978 which states that when noise levels exceed 90 dba for an 8 hour period, hearing protection must be worn.

The equipment used was a BRUEL & KJAER Impulse Precision Sound Level Meter Type 2209 c/w a BRUEL & KJAER Octave Filter Set Type 1613 and calibrations were checked with a BRUEL & KJAER Sound Level Calibrator Type 4230. All readings were taken using the slow response setting and they conformed well to those taken by B. K. Mark, March 1983.

Robert Adams.

R. R. Adams
Asst. to Transportation Engineer

RRA:jb

cc. M. D. Grant
D. I. Harrison

Attachments

NOISE SURVEY

PART I GENERAL DATA

STN. ID.# ____ TIME: 14:30 - 15:50

STN. NAME Hamilton Service Centre DATE: 84 05 17

WINDS: VELOCITY 0 DIRECTION: 0 TEMP: 15°C

GROUND CONDITIONS: Grass @ position 1, 2, 3, 4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.5

GENERAL COMMENTS: Background noise: birds, trucks, train engine (82 dba), train cars (68 dba) cranes working

HEATER: ____ OFF ____ ON ____

PART II FLOW DATA N/A

METER ROTATION: ____ TIME: ____ PER ____ REVOLUTIONS

STATIC PRESSURE: ____ DIFFERENTIAL PRESSURE: ____ PLATE SIZE: ____

FLOW: ____ OUTLET PIPE DIA: ____

FLOW SPEED ____ FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LIN
1 2	48 50	58	67	59	65	62	56	50	44	43	39	27	12	3	4	72
3 4	52 48	59	69	60	70	69	61	54	46	44	43	25	12	4	4	75
5 6	52 53	62	70	62	68	65	58	55	54	46	37	27	23	5	4	76
7 8	55															
9 10																
11 12																

SIGNATURE OF TESTER Robert Adams

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 23:30

STN. NAME Hamilton Service Centre

DATE: 84 05 17

WINDS: VELOCITY

DIRECTION:

TEMP:

GROUND CONDITIONS: concrete floor

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.6

GENERAL COMMENTS: Inside compressor building

HEATER:

OFF

ON

PART II FLOW DATA N/A

METER ROTATION:

TIME: PER REVOLUTIONS

STATIC PRESSURE:

DIFFERENTIAL PRESSURE:

PLATE SIZE:

FLOW:

OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LIN
1	86	92	93	94	65	67	79	89	83	82	82	75	67	58	41	93
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																

SIGNATURE OF TESTER Robert Adams.

Consumer and Corporate Affairs Canada
Consommation et Corporations Canada

C.N.G. TEST RECORD SHEET

DISTRICT NIAGARA DATE Oct 14 1983

INSTALLATION# 100/A LOCATION UNION GAS STRATHEARNE

GAS WEIGHT ERROR CALCULATIONS:

Scale Serial # W557 Test Tank Serial # HA 993

	Full Flow Test	Slow Flow Test
(A) Test Tank Weight After Filling....	39.695 kgs	39.817 kgs
(B) Test Tank Weight Prior to Filling.	35.335 kgs	36.974 kgs
(C) True Weight of Gas (A - B)........	4.360 kgs	2.843 kgs
(D) Registered Weight of Gas..........	4.382 kgs	2.850 kgs
(E) Error (C - D) in Weight...........	0.022 kgs	.007 kgs
(F) Filling Time......................	37.5 sec	31.0 sec
FIELD NOTE ERROR: $\frac{D - C}{D}$ X 100 $\frac{4.382 - 4.360}{4.382}$ $\frac{2.850 -}{2.850}$ *Tolerance = + or - 1% (one)	+0.5%	+0.25%
REGISTER CALCULATION CHECK: D x Registered Price Per KG....36	$1.5775	$1.026
Registered Total Price............	$1.58	$1.03
(G) ERROR (Tolerance $0.01)..........	$.0025	$.004
Full pressure	2600 psi	2600 psi
Gas temperature		

REMARKS:

Weight kit 123 M 20 kg 44-1 41

20 kg 44-1 37

10 kg 44-14 14

FN 101636

INSPECTOR'S SIGNATURE

APPENDIX 3

NOISE LEVEL STUDIES

W0176-2/78 **MEMORANDUM**

TO: D. B. Davis **DEPT/OFFICE:** Head **DATE:** 1984 05 24

FROM: R. R. Adams **DEPT/OFFICE:** Head

RE: Hamilton NGV Compressor Station Noise Level

Noise levels were measured at the Hamilton Service Centre on Thursday, May 17, 1984 in the afternoon and at midnight. These times were selected to correspond to those used by B. K. Mark and D. I. Harrison in previous studies. The locations selected were those from the previous study by B. K. Mark.

The values observed ranged from 48 to 55 dba in the afternoon and from 44 to 52 dba at midnight. The background noise is listed on the data sheet. The stroking was hardly audible in the afternoon but with the lower background noise at midnight, the stroking of the compressor was audible from all locations. The level inside the building was 86 dba.

As outlined by B. K. Mark in his memo to you (83 03 16) the station clearly meets the Occupational Health and Safety Act, 1978 which states that when noise levels exceed 90 dba for an 8 hour period, hearing protection must be worn.

The equipment used was a BRUEL & KJAER Impulse Precision Sound Level Meter Type 2209 c/w a BRUEL & KJAER Octave Filter Set Type 1613 and calibrations were checked with a BRUEL & KJAER Sound Level Calibrator Type 4230. All readings were taken using the slow response setting and they conformed well to those taken by B. K. Mark, March 1983.

Robert Adams.

R. R. Adams
Asst. to Transportation Engineer

RRA:jb

cc. M. D. Grant
D. I. Harrison

Attachments

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 14:30 - 15:50

STN. NAME Hamilton Service Centre

DATE: 84 05 17

WINDS: VELOCITY 0 DIRECTION: 0 TEMP: 15°C

GROUND CONDITIONS: Grass @ position 1, 2, 3, 4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.5

GENERAL COMMENTS: Background noise: birds, trucks, train engine (82 dba), train cars (68 dba) cranes working

HEATER: OFF ON

PART II FLOW DATA N/A

METER ROTATION: TIME: PER REVOLUTIONS

STATIC PRESSURE: DIFFERENTIAL PRESSURE: PLATE SIZE:

FLOW: OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1	48	58	67	59	65	62	56	50	44	43	39	27	12	3	4	7
2	50															
3	52	59	69	60	70	69	61	54	46	44	43	25	12	4	4	7
4	48															
5	52															
6	53	62	70	62	68	65	58	55	54	46	37	27	23	5	4	7
7	55															
8																
9																
10																
11																
12																

SIGNATURE OF TESTER Robert Adams

NOISE SURVEY

PART I GENERAL DATA

STN. ID.# ______ TIME: 23:30

STN. NAME Hamilton Service Centre DATE: 84 05 17

WINDS: VELOCITY ______ DIRECTION: ______ TEMP: ______

GROUND CONDITIONS: concrete floor

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.6

GENERAL COMMENTS: Inside compressor building

HEATER: ______ OFF ______ ON ______

PART II FLOW DATA N/A

METER ROTATION: ______ TIME: ______ PER ______ REVOLUTIONS

STATIC PRESSURE: ______ DIFFERENTIAL PRESSURE: ______ PLATE SIZE: ______

FLOW: ______ OUTLET PIPE DIA: ______

FLOW SPEED ______ FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1 2	86	92	93	94	65	67	79	89	83	82	82	75	67	58	41	93
3 4																
5 6																
7 8																
9 10																
11 12																

SIGNATURE OF TESTER Robert Adams.

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 23:30 - 0:30

STN. NAME Hamilton Service Centre

DATE: 84 05 17/18

WINDS: VELOCITY 5 - 10 kmph DIRECTION: Southerly

TEMP: 9 °C

GROUND CONDITIONS: Grass @ position 1, 2, 3, 4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.6

GENERAL COMMENTS: Background noise: traffic, A/C unit on store roof (pos 1), power lines (pos 1, 2, 3 and 4)

HEATER: OFF ON

PART II FLOW DATA N/A

METER ROTATION: TIME: PER REVOLUTIONS

STATIC PRESSURE: DIFFERENTIAL PRESSURE: PLATE SIZE:

FLOW: OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1 2	44 45	53	61	53	55	57	55	46	39	39	33	23	11	3	3	71
3 4	45 46	56	64	55	61	62	55	47	39	41	33	23	18	8	3	72
5 6	50 51	58	64	58	59	58	57	53	52	43	35	26	17	4	3	7
7 8	52															
9 10																
11 12																

SIGNATURE OF TESTER Robert Adams.

0176 2 78

Memorandum

TO D. B. Davis DEPT/OFFICE. Head DATE 1983-03-16

FROM B. K. Mark DEPT/OFFICE. Head

RE Hamilton CNG Compressor Station Noise Levels

Noise levels with the CNG Compressor Station in operation at the Hamilton Service Centre were measured on Monday, March 14, 1983 in the afternoon and at midnight. These observations are a follow-up to the noise levels measured by D. I. Harrison in September, 1982 which are recognized as the base readings before the compressor station was constructed. The noise level was also monitored inside the compressor building with the compressor in operation and at the property line along Strathearne Avenue (position #3) when the blowdown was opened.

The noise levels observed were 48dba to 54 dba in the afternoon and 47 dba to 56 dba at night. In the afternoon, the background noise consisted of traffic, birds and a welder operating near the garage of the service centre building. During the night readings there was an appreciable noise from the rail yard. There is no significant rise in noise levels between the base readings and the present readings. The stroking action of the compressor was audible from positions 2 through 7. The highest noise level observed was at position 7 which is approximately 60 feet from the compressor building. Inside the building the observed noise level was 82 dba.

As specified in the Occupational Health and Safety Act, 1978 and Regulations for Industrial Establishments hearding protection must be worn when the daily exposure is 90 dba for an 8 hour period. Therefore, the operation of the compressor would easily meet these standards. When the blowdown was opened, the noise level observed from position #3 was 82 dba. Passing trains were observed to have a peak reading of 74 dba for the engines and a reading of 64 dba for the cars. These noise levels were also observed from position #3.

The equipment used was a BRUEL & KJAER Impulse Precision Sound Level Meter Type 2209 c/w a BRUEL & KJAER Octave Filter Set Type 1613 and calibrations were checked with a BRUEL & KJAER Sound Level Calibrator Type 4230. All readings were taken using the slow response setting.

Brian K Mark

B. K. Mark,
Asst. Transportation Design Engineer

BKM/at

cc: M. D. Grant
D. I. Harrison

Attachments (7)

NOISE SURVEY

PART I GENERAL DATA

STN. ID.# ____________ TIME: 13:40 - 15:45

STN. NAME Hamilton Service Centre DATE: 1983-03-14

WINDS: VELOCITY 17 Km DIRECTION: Southerly TEMP: 9.3°C

GROUND CONDITIONS: Grass @ position 1,2,3,4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	94.0	94.0

GENERAL COMMENTS: Stroking of compressor audible at positions 3,4,5,6 and 7
Background noise consists of birds, traffic and welder working near garage

HEATER: ____________ OFF ____________ ON ____________

PART II FLOW DATA N/A

METER ROTATION: ____________ TIME: ______ PER ______ REVOLUTIONS

STATIC PRESSURE: ____________ DIFFERENTIAL PRESSURE: ____________ PLATE SIZE: ____________

FLOW: ____________ OUTLET PIPE DIA: ____________

FLOW SPEED ____________ FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1	48	58	67	58	63	62	61	48	44	46	42	30	12	5	5	7
2	49															
3	53	60	70	60	65	68	56	48	44	45	39	35	22	11	5	7
4	50															
5	51															
6	53	62	71	62	69	67	66	58	51	46	43	39	23	6	5	7
7	54															
8																
9		For position #3														
10		Blowdown opened - 82 dba														
11																
12																

SIGNATURE OF TESTER

NOISE SURVEY

PART I GENERAL DATA

STN. ID.# ____ TIME: 00:00 - 01:29

STN. NAME Hamilton Service Centre DATE: 1983-03-15

WINDS: VELOCITY 17 Km DIRECTION: Westerly TEMP: 6°C

GROUND CONDITIONS: Grass @ position 1,2,3,4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.5	94.0

GENERAL COMMENTS: Stroking of compressor audible at position 2,3,4,5, and 7
Heavy background noise from rail yard at position 6

HEATER: Flag Flapping at possition 7 OFF ____ ON ____

PART II FLOW DATA

METER ROTATION: ____ TIME: ____ PER REVOLUTIO

STATIC PRESSURE: ____ DIFFERENTIAL PRESSURE: ____ PLATE SIZE: ____

FLOW: ____ OUTLET PIPE DIA: ____

FLOW SPEED ____ FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500
1	48	56	64	54	58	62	57	47	47	43	38	22	12	4	5
2	47														
3	48	55	64	56	62	60	54	49	48	46	35	26	26	11	5
4	47														
5	51														
6	47	59	67	59	64	62	52	48	51	48	35	31	16	6	4
7	56														
8															
9		For position #3													
10		train on track - engines 74 dba													
11					- cars 54 dba										
12															

SIGNATURE OF TESTER Brian K

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

STN. NAME CNG Compressor Station

TIME: 09:15 - 09:30

DATE: 1983-03-15

WINDS: VELOCITY DIRECTION:

TEMP: 2.3°C

GROUND CONDITIONS: concrete

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.7

GENERAL COMMENTS: Inside building

HEATER: OFF ON

PART II FLOW DATA

METER ROTATION: TIME: PER REVOLUTIONS

STATIC PRESSURE: DIFFERENTIAL PRESSURE: PLATE SIZE:

FLOW: OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1	82	88	86	92	66	68	72	75	77	84	77	66	63	50	34	85
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																

SIGNATURE OF TESTER Brian K Mark

Memorandum

TO M. Grant DEPT/OFFICE Head Office DATE 1982-09-28

FROM D.I. Harrison DEPT/OFFICE G.C.E.

RE **HAMILTON S.C. NOISE LEVELS**

Current background noise levels for the Hamilton S.C. were measured Thursday, September 23, 1982 in the afternoon and at midnight. The purpose of these observations was to determine background levels prior to the installation of the C.N.G. compressor. The results of these measurements and a sketch of the area indicating the location of each observation are attached.

These observations of 48 to 52 dba afternoon and 47 to 50 dba night are the lowest background readings that can be realistically expected. Both steel plants (on opposite side of railway tracks) were shut down and there was no discernable noise coming from their directions. The only noticeable noises other than the background traffic and animal noises were the passing trains and the rooftop heating/cooling unit on the Union Gas office. Passing trains caused a peak reading of 66 dba for the engines and readings of 54 to 57 dba for the various cars when observed at position #1 (by the Union Gas sign in the front lawn). The heating/cooling unit was loud enough to be identifiable at night and was included in the position #1 night observations. As observed at position #7 this unit has a minimal effect on the readings, only one dba at this position.

The equipment used in this analysis was a BRUEL & KJAER Impulse Precision Sound Level Meter Type 2209 c/w a BRUEL & KJAER Octave Filter Set Type 1613 and calibrations were checked with a BRUEL & KJAER Sound Level Calibrator Type 4230. All readings were taken using the slow response setting.

If you have any further questions concerning the observations, interpretation of, or measurement techniques please contact me.

D.I. Harrison, P. Eng.,
Gas Control Equipment Engineer

DIH:pm

cc: D.W. McCartney

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 23:30 - 0.35

STN. NAME Hamilton S.C.

DATE: 82-09-23/24

WINDS: VELOCITY 0 DIRECTION: 0 TEMP:

GROUND CONDITIONS: Wet grass positions 1, 2, 3, 4 & 7
Gravel positions 5 & 6

CHECK	START		FINISH
BATTERY:	O.K.		O.K
CALIBRATION:	93.6		93.

GENERAL COMMENTS: Heating/cooling unit on top of Union's office bldg. in #1, plants in background were quiet.

HEATER: N/A OFF ON

PART II FLOW DATA N/A

TER ROTATION: TIME: PER REVOLUTIONS

STATIC PRESSURE: DIFFERENTIAL PRESSURE: PLATE SIZE:

FLOW: OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	L
	50	58	64	57	59	60	58	49	45	41	36	31	23	5	5	
2	48															
3	47	56	63	55	57	57	57	47	44	42	34	29	19	5	5	
4	48															
5	48															
6	49	58	64	57	60	59	56	51	45	43	37	30	14	5	5	
7	47	(without roof top unit, 48 with rooftop unit)														
8																
9		For position #1														
10		train on track			- engines 66 dba											
					- cars 54 to 57 dba											

SIGNATURE OF TESTER

NOISE SURVEY

RT I GENERAL DATA

TN. ID.# ______ TIME: 14:25 - 15:45

IN. NAME Hamilton S.C. DATE: 82-09-23

NDS: VELOCITY Gusty 0-10 km DIRECTION: Variable TEMP: ______

ROUND CONDITIONS: Wet grass positions 1, 2, 3, 4 & 7
Gravel positions 5 & 6

CHECK	START	FINISH
BATTERY:	O.K.	O.K
CALIBRATION:	93.4	93.4

GENERAL COMMENTS: CNG building partially constructed. Background noise consists of birds, traffic, dogs & crickets.

ATER: ______ OFF ______ ON ______

RT II FLOW DATA N/A

ER ROTATION: ______ TIME: ______ PER ______ REVOLUTIONS

ATIC PRESSURE: ______ DIFFERENTIAL PRESSURE: ______ PLATE SIZE: ______

OW: ______ OUTLET PIPE DIA: ______

FLOW SPEED ______ FT./SEC.

PART III NOISE MEASUREMENTS

SITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1	49 48	60	68.	58	65	65	56	52	44	45	40	35	28	7	5	7
3	50 50	61	69	62	65	64	59	52	41	42	39	27	25	7	5	7
6	51 52	67	75	67	70	74	59	50	43	40	38	42	18	5	5	7
8	49															
10																
1 12																

SIGNATURE OF TESTER ______

APPENDIX 4

DRIVER'S WEEKLY FUEL RECORD

DRIVER'S WEEKLY FUEL RECORD

During the first year of the study, April 1st, 1983 to March 31st, 1984, each driver was issued a 'Driver's Weekly Fuel Record', Form #2673-1983/03.

During the week, the driver recorded fuel data and forwarded the form to the Vehicle Supervisor at the end of the week.

An explanation of each entry on the sheet is provided and a sample sheet has been filled out.

The form was replaced by Form #2673-1983/09 on April 1st, 1984 to accommodate the slow-fill facilities. A similar explanation and example are provided.

APPENDIX #4

CLARIFICATION OF TYPICAL ENTRIES

①	Jan. 1/83	DATE - Must be Given.
②	36,000	ODOMETER reading taken before vehicle leaves Company yard - Must be Given.
③	3.125	FUEL - kilograms of natural gas - Give three decimal places.
④		CHECK - 'G' for gasoline or 'N' for natural gas. This is the fuel that is used when vehicle leaves Company yard - Must be Given.
⑤	36,050	ODOMETER at switch-over - Must be Given (eg. No Fuel)
⑥	A	Switch-over code. To be filled when problems occur and shift cannot be completed on original fuel - Must be Given.
⑦	Jan. 1st	- See ①
⑧	36,075	- ODOMETER at time of fill.

NOTE: It has been assumed that 36,075 minus 36,050 kilometres has been driven on gasoline to return for fuel.

⑨	4.875	- FUEL - kilograms of natural gas - See ③
⑩		CHECK - See ④
⑪	36,100	ODOMETER at end of shift.
⑫	Jan. 2/83	See ①
⑬	36,100	- ODOMETER reading - See ②

NOTE: When ⑪ is given ⑬ must agree with ⑪

⑭	36.1	FUEL - litres of gasoline. Given 1 decimal place.
⑮		CHECK - See ④
⑯	36,150	ODOMETER reading - See ⑤
⑰	36,160	ODOMETER at end of shift - See ⑪
⑱	B	S.W.H. codes - See ⑥
⑲	Jan. 5/83	DATE - See ⑬ and Note.
⑳	36,160	ODOMETER reading - See ②

...../2

㉑	10.000	FUEL - See ③
㉒	36,220	ODOMETER at switch-over.
㉔	36,225	ODOMETER reading at end of weekly shift.
㉕		END OF WEEKLY SHIFT - Refer to note at bottom of page and comments.

2673 - 1983/03

DRIVER'S WEEKLY FUEL RECOF

Date — From

To

Driver

Vehicle Number

Note: Completed form is to be turned in to Vehicle Supervisor at the end of the last weekly shift.

Date	Start of Shift or After Fill					End of Shift or at Switchover			FOR H.O. USE ONLY	
	Odometer	Fuel		Fuel Check*		Odometer At Switchover	Odometer End of Shift	Switch-over Code	Dist. On G	Dist. On N
		Litre of G.	Kilos of N.	**G	**N					
①	②		③		④	⑤		⑥		
⑦	⑧		⑨	⑩			⑪			
⑫	⑬	⑭			⑮	⑯	⑰	⑱		
⑲	⑳		㉑		㉒	㉓	㉔			

Switchover Codes:
A — Out of Natural Gas
B — Vehicle Problems on Natural Gas
C — Vehicle Problems other than Natural Gas
D — End of Weekly Shift
E — Other - Use Comments Below

25

Date	Comments or Problems

NOTE: Vehicle is to be operated on Natural Gas except upon return to Company yard on last weekly shift.

* Indicate type of fuel used when leaving Company yard. One (1) check per line must be given. ** G - Gasoline ** N - Natural

2673 - 1983/03

DRIVER'S WEEKLY FUEL RECO

Date — From	To
Driver	Vehicle Number

Note: Completed form is to be turned in to Vehicle Supervisor at the end of the last weekly shift.

Date	Start of Shift or After Fill			Fuel Check*		End of Shift or at Switchover			FOR H.O. USE ONLY	
	Odometer	Fuel Litre of G.	Fuel Kilos of N.	**G	**N	Odometer At Switchover	Odometer End of Shift	Switchover Code	Dist. On G	Dist. O N
Jan.1/83	36,000		3.125		✓	36,050		A		
Jan.1/83	36,075		4.875	✓			36,100			
Jan.2/83	36,100	36.1			✓	36,150	36,150	B		
Jan.5/83	36,160		10.000		✓	36,220	36,225	See Belo		

Switchover Codes:
- A — Out of Natural Gas
- B — Vehicle Problems on Natural Gas
- C — Vehicle Problems other than Natural Gas
- D — End of Weekly Shift
- E — Other - Use Comments Below

Date	Comments or Problems
Jan.5/83	End of Shift.

NOTE: Vehicle is to be operated on Natural Gas except upon return to Company yard on last weekly shift.

* Indicate type of fuel used when leaving Company yard. One (1) check per line must be given. ** G - Gasoline ** N - Natural

2ND YEAR
APR. 1, 1984 TO MAR. 31, 1984
CLARIFICATION OF TYPICAL ENTRIES

①, ⑨, ⑯, ㉓, ㉙	- Apr. 1 to Apr. 5	-	Date - Must be given.
②, ⑩, ⑰, ㉔, ㉚	- 50,000 km to 50,450	-	Odometer readings taken before vehicle leaves company yard - Must be given.
③, ⑪, ⑱, ㉕, ㉚	- 2,800, 2,800, 2,800, 2,800, 800	-	Pressure readings taken on vehicle after disconnecting the natural gas slow-fill hose and before leaving company yard.
④	✓	-	Check "G" for gasoline OR "N" for natural gas. This is the fuel that is used when vehicle leaves company yard - Must be given.
⑤	- 50,150	-	Odometer at switchover to gasoline.
⑥	- 50,175	-	Odometer at end of shift.
⑦, ⑮, ㉑, ㉘, ㉟	- 400, 800, 2,800, 800, 1,000	-	Pressure readings taken on vehicle before connecting slow-fill hose to vehicle at the end of day shift.
⑧	- A	-	Out of natural gas.
⑪,	- 50	-	Fuel - litres of gasoline.
⑬,	✓	-	See ④
⑭, ⑳, ㉗, ㉞	- 50,250, 50,300, 50,450, 50,580	-	See ⑥
⑲,		-	See ④
⑳	- 50,300	-	See ⑥
㉒,	- B	-	Vehicle problems on natural gas.
㉖		-	See ④
㉛,	- 11,145	-	Fuel - natural gas dispensed and N.G. in kilograms.
㉜,			
㉝,	- 50,575	-	See ⑤

2673 1983-09

DRIVER'S WEEKLY FUEL REC

Date — From	To
Driver	Vehicle Number

Note: Completed form is to be turned in to Vehicle Supervisor at the end of the last weekly shift.

Date	Start of Shift or After Fill							End of Shift or at Switchover				
		Slow-Fill		Fuel		Fuel Check*				Slow-Fill		
	Odometer	Temp	Pressure	Litre of G	Kilos of N	**G	**N	Odometer at Switchover	Odometer End of Shift	Temp	Pressure	Switch-over Code
Apr.1/84	50,000		2,800				✓	50,150	50,175		400	A
Apr.2/84	50,175		2,800	50			✓		50,250		800	
Apr.3/84	50,250		2,800			✓			50,300		2,800	B
Apr.4/84	50,300		2,800				✓		50,450		800	
Apr.5/84	50,450		800		11.145		✓	50,575	50,580		1,000	See Below

Switchover Codes:
A — Out of Natural Gas
B — Vehicle Problems on Natural Gas
C — Vehicle Problems other than Natural Gas
D — End of Weekly Shift
E — Other - Use Comments Below

Date	Comments or Problems
Apr.5/	End of shift.

NOTE: Vehicle is to be operated on Natural Gas except upon return to Company yard on last weekly shift.

- Indicate type of fuel used when leaving Company yard. One (1) check per line must be given.

** G - Gasoline ** N - Natural

APPENDIX 5

COMPRESSOR HYDRO COSTS

there was no evidence of any valve recession after a natural gas utilization of 92% (24 886 km on NG and 2203 km on gasoline).

In general, engine life is expected to increase with the use of natural gas. Oil change intervals have been doubled from every three to every six months, but this may not be the case for vehicles which travel higher annual distances.

Table 5/ Vehicle Maintenance Comparison

Vehicle Number	Study Group Cost	Study Group km	Control Group Cost	Control Group km	Study /km	Control /km
375-78	984.00	7 451	1323.00	70 401	13.2	1.9
380-82	1899.00	26 524	526.00	11 906	7.2	4.4
387-82	2387.00	38 664	1620.00	52 447	6.2	3.1
510-80	2684.00	31 827	2620.00	12 853	8.4	20.4
540-83	1220.00	13 959	673.00	14 439	8.7	4.7
650-80	1750.00	11 286	2309.00	45 980	15.5	5.0
762-82	2233.00	31 108	754.00	56 154	7.2	1.3
773-80	1549.00	10 473	1244.00	8 881	14.8	14.0
778-80	1925.00	6 462	1258.00	7 189	29.8	17.5
779-80	1341.00	10 969	572.00	8 759	12.2	6.5
800-77	1116.00	14 183	680.00	7 566	7.9	9.0
801-83	1106.00	10 361	813.00	13 913	10.7	5.8
814-79	1319.00	10 991	1194.00	11 344	12.0	10.5
817-78	2168.00	10 880	939.00	11 331	19.9	8.3
826-79	1313.00	12 034	2068.00	6 764	10.9	30.6
862-80	633.00	18 608	949.00	29 527	3.4	3.2
867-82	1180.00	27 200	628.00	10 232	4.3	6.1
873-80	941.00	19 588	657.00	19 813	4.8	3.3
876-79	1503.00	5 338	2328.00	6 583	28.2	35.4
880-79	1874.00	13 157	1282.00	3 564	14.2	36.0
885-80	1559.00	13 618	1065.00	23 967	11.4	4.4
887-77	1621.00	11 566	2400.00	13 236	14.0	18.1
892-77	1835.00	7 562	1137.00	8 708	24.3	13.1
896-78	1821.00	2 271	897.00	6 968	80.2	12.9
898-80	1506.00	5 178	2780.00	17 230	29.1	16.1

Vehicle Groups as Defined in Section 5.2, "Fuel Economy Data"
(all vehicles included)

	Study Group		Control Group
	Total ($/km)	NG($/km)	($/km)
Group A	6.7	1.6	4.7
Group B	13.8	3.6	11.0
Group C	25.8	6.9	14.5
Group D	9.7	2.8	5.3
Group E	12.3	1.9	35.9

7/ OIL ANALYSIS

Oil samples were taken for analysis from every vehicle every three months -- or 5000 km -- whichever came first.

Appendix 8 gives the odometer reading at each oil change and indicates the reason for the change. During the first year of the study, 83% of the oil changes were carried out as a result of an unusually high bearing wear rate, indicated by the high copper content in the oil samples. This occurred extensively between February 28, 1983 and March 31, 1984.

In September of 1984, Wear Check, who carried out the oil analysis, was notified by Imperial Oil that in February of 1983, they had added between 109 and 120 ppm (parts per million) of copper to the base oil, and thus, the oil sample analysis showed an increase from between 0 and 30 to 150 ppm. Therefore, the report of unusually high bearing wear in the 1984 fiscal MTC Report is erroneous.

As a result of the analysis carried out by Wear Check, it appears that the oil change intervals can be increased to 10 000 km or every six months with natural gas vehicles.

8/ VEHICLE OPERATION AND MAINTENANCE PROBLEMS

Several major problems were experienced with the study group. These are outlined, along with a description of the action taken to alleviate the problem. In addition, the industry status with respect to the problems has been included.

8.1/ Freeze-off

Problem
When operating a vehicle on NG, the pressure must be reduced to atmospheric before the gas is mixed with air and allowed to enter the engine. This large pressure drop results in expansion of the NG, a process that lowers the temperature of the gas. The regulator becomes very cold and any water in the gas will freeze. As a result, NG cannot pass through the regulator, and the fuel supply to the engine is cut off. This problem was experienced early in the study even though the regulators were originally equipped with an electrical heating system.

Action
It was apparent that the situation could be resolved by adequate heating of the regulator to prevent the freeze-off or by adequate drying of the NG. Modification of the regulator to an engine coolant heating system that had a better heat transfer capacity eliminated freeze-off. A need to dry the gas was not apparent with this system; however, if the NG water content is high (greater than approximately 15 lb/million scf), it may be necessary to dry the gas as well. In the industry, the majority of the regulators used have engine coolant heating.

8.2/ Stalling

Problem
During the study, some vehicles experienced a recurring stalling problem at idle or when coming off of the throttle.

Action
This problem was resolved by changing the method of setting up the sensitivity adjustment on the idle circuit. The problem here was one of lack of knowledge rather than design. With a two-stage regulator, this adjustment was extremely sensitive; through experience, however, the mechanics have become accustomed to making this adjustment. Today, the majority of regulators have a three-stage design rather than the two-stage installed in our study group. With the new regulators, the idle

circuit is not as sensitive and, therefore, is much easier to set up.

8.3/ Cold Starting

Problem

Difficulty in starting on NG was experienced with some vehicles, especially in cold weather (below -18°C)

Action

Some of the starting problems were corrected by better regulator setup and better driver education. NG is only flammable when mixed with air in the ratio of between 4.5 and 14.5% by volume; thus, if the vehicle is over or under primed, it will not start.

The starting problem still exists on extremely cold winter mornings (below -18°C). It is felt that this is due partially to the poor condition of the vehicle ignition and cranking systems. In addition, poor regulator performance is to blame. In cold weather, the diaphragms tend to harden, thereby not allowing gas to pass into the engine at the required rate. Regulators today have diaphragms made of more suitable materials, and the cold start problem is becoming less predominant in vehicles converted in 1985.

8.4/ Power Loss

Problem

Most of the vehicles used in this study experienced a loss of power on gasoline and/or NG after conversion. (See Table 9-3 in Appendix 9.)

Action

Some of the power loss problems on NG were corrected by changing the air/fuel ratio by adjusting the power screw in the NG dry hose between the regulator and the mixer.

Some vehicles had original regulators that were too small to deliver the required volume of NG. These regulators were replaced or modified for a larger volumetric capacity. It should be noted that 10% power loss is the minimum loss expected when running on NG. This occurs because a minimum of 10% of the intake air is displaced by the NG.

The power loss on gasoline occurs due to the presence of a mixer mounted directly under the carburetor. This mixer restricts the flow of air into the engine, resulting in a loss of power. In the industry today, better mixer designs are available that do not restrict the airflow when the vehicle is operating on gasoline.

8.5/ Vehicle Breakdown

As the study progressed into its second year, vehicle breakdown resulting from poor wiring became a dominant problem. Wiring connections corroded or simply came apart because of vehicle vibration.

Action

This problem was solved by soldering the wire connections and insulating the connections properly. Today, better quality connectors and the generally accepted practice of soldering have helped bring the wiring up to original equipment manufacturer (OEM) standards.

8.6/ Gas Leaks -- Fittings and Tubings

Problem
Gas leaks at various fittings and tubing connections became a problem.

Action
These leaks were repaired and, at the present time, a soap test is carried out at each PM-B inspection (every six months). In this test, a soap solution is sprayed on each connection and any leaks will cause the soap to bubble. The tube connections that were used on the demonstration fleet are no longer used in the industry, and better sealants for the National Pipe Thread (NPT) threads are available. This has reduced the problem of NG leaks significantly on later conversions.

8.7/ Gas Leaks -- Inlet Seals of Regulators

Problem
The inlet seals of the regulators experienced a very short life, resulting in a natural gas leaking problem. This is not caused by the design of the seal, but the design of the inlet itself (only on Renzo Landi Regulator Models SM, M, and SS).

Action
To date, the problem has not been corrected, but it has been resolved by replacing the O ring inlet seal at each PM-B inspection, thereby replacing it before it starts to leak. A new teflon seal is being experimented with and its life has been found to be approximately one year -- twice the original seal's life.

8.8/ Ignition Breakdown

Problem
Some of the vehicles in the study experienced breakdowns of the dual-curve ignition module, which advances the spark for optimal performance on NG.

Action
Some mounting locations of the module allowed water to enter the unit, causing corrosion and shorting. Better locations were found, and the units are now sealed with silicone before installation.

8.9/ Fuel Gauge Malfunction

Problem
Malfunction of the NG fuel gauge was common for the vehicles in the demonstration fleet.

Action
The analog unit was replaced with a rugged gauge that uses sequential light-emitting diode (LED) lights. There are many durable units available on the market today; however, accuracy is still a problem.

8.10/ Gas Leaks -- Fill Probe

Problem
Problems with the fill probe were encountered during and after fuelling, especially during the winter months.

During fuelling, leaks would develop between the fill probe and refuelling block, because the O rings that make the seal become nicked when the probe is inserted into the block.

Action
This problem was helped by champering the female refuelling block, guiding the fill probe into proper alignment, and partially by using O rings made of viton with a 70 durometer hardness.

8.11/ Gas Leaks -- Check Valve

Problem
Another problem experienced during and at the end of the refuelling process was leakage past the check valve in the fuelling block. This back leakage pressurized the seal of the dust plug and made its removal difficult. The leak resulted from small pieces of the fill probe O ring

lodging under the seal of the check valve or the ice buildup under the check valve, caused by the large pressure drop across the valve during refuelling.

Action

Although these problems have not been eliminated, better refuelling blocks are available today and a new fill probe with recessed O rings is being experimented with.

8.12/ Discussion

In the demonstration fleet, most of these problems disappeared when the slow-fill operation was installed. The fill probes were replaced with quick-disconnect couplers. The check valve continued to be a problem, but it was not significant because the O ring material from the fill probe was no longer entering the system. The high pressure drop across the valve is eliminated with the slow-fill facilities, so valve freezing is eliminated.

All of these problems resulted in required maintenance to correct or service the problem. Appendix 6 outlines the costs of repairs and maintenance of the problems discussed on a per vehicle basis.

It should be noted that a conversion done today (which would meet the new Ontario Utilities Specifications given in Appendix 11) would not experience the majority of these problems.

9/ CONCLUSION

During the two-year study period from April 1, 1983 to March 31, 1985, natural gas has proven to be an economical and practical alternative to gasoline.

By operating on natural gas with a two-year average utilization of 77%, the 25 vehicle demonstration fleet saved over $25,000 in gasoline cost, a 35% savings. With ever-rising gasoline prices, this savings will continue to increase.

Although several problems were encountered with the compressor operation, most have been solved, and the service time on the unit has been reduced significantly. In addition, a great deal of experience was gained which would eliminate many problems in a similar future installation.

Vehicle maintenance problems have also been brought under control through both experience and better equipment. As was mentioned, recently converted vehicles do not encounter the majority of the problems experienced during this study and, thus, maintenance costs are significantly lower.

Overall, the study went well and the experience has indicated that natural gas has tremendous potential as an alternative vehicle fuel. As gasoline prices escalate and public awareness grows, natural gas will play a significant role as the most attractive and the safest vehicle fuel.

NOISE SURVEY

PART I GENERAL DATA

STN. ID.# ____________ TIME: 23:30 - 0:30

STN. NAME Hamilton Service Centre DATE: 84 05 17/18

WINDS: VELOCITY 5 - 10 kmph DIRECTION: Southerly TEMP: 9 °C

GROUND CONDITIONS: Grass @ position 1, 2, 3, 4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.6	93.6

GENERAL COMMENTS: Background noise: traffic, A/C unit on store roof (pos 1), power lines (pos 1, 2, 3 and 4)

HEATER: ____________ OFF ____________ ON ____________

PART II FLOW DATA N/A

METER ROTATION: ____________ TIME: ____ PER ____ REVOLUTIONS

STATIC PRESSURE: ____________ DIFFERENTIAL PRESSURE: ____________ PLATE SIZE: ____

FLOW: ____________ OUTLET PIPE DIA: ____________

FLOW SPEED ____________ FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1 2	44 45	53	61	53	55	57	55	46	39	39	33	23	11	3	3	71
3 4	45 46	56	64	55	61	62	55	47	39	41	33	23	18	8	3	72
5 6	50 51	58	64	58	59	58	57	53	52	43	35	26	17	4	3	70
7 8	52															
9 10																
11 12																

SIGNATURE OF TESTER Robert Adams.

0176 2 78

Memorandum

TO D. B. Davis DEPT/OFFICE. Head DATE 1983-03-16

FROM B. K. Mark DEPT/OFFICE. Head

RE Hamilton CNG Compressor Station Noise Levels

Noise levels with the CNG Compressor Station in operation at the Hamilton Service Centre were measured on Monday, March 14, 1983 in the afternoon and at midnight. These observations are a follow-up to the noise levels measured by D. I. Harrison in September, 1982 which are recognized as the base readings before the compressor station was constructed. The noise level was also monitored inside the compressor building with the compressor in operation and at the property line along Strathearne Avenue (position #3) when the blowdown was opened.

The noise levels observed were 48dba to 54 dba in the afternoon and 47 dba to 56 dba at night. In the afternoon, the background noise consisted of traffic, birds and a welder operating near the garage of the service centre building. During the night readings there was an appreciable noise from the rail yard. There is no significant rise in noise levels between the base readings and the present readings. The stroking action of the compressor was audible from positions 2 through 7. The highest noise level observed was at position 7 which is approximately 60 feet from the compressor building. Inside the building the observed noise level was 82 dba.

As specified in the Occupational Health and Safety Act, 1978 and Regulations for Industrial Establishments hearding protection must be worn when the daily exposure is 90 dba for an 8 hour period. Therefore, the operation of the compressor would easily meet these standards. When the blowdown was opened, the noise level observed from position #3 was 82 dba. Passing trains were observed to have a peak reading of 74 dba for the engines and a reading of 64 dba for the cars. These noise levels were also observed from position #3.

The equipment used was a BRUEL & KJAER Impulse Precision Sound Level Meter Type 2209 c/w a BRUEL & KJAER Octave Filter Set Type 1613 and calibrations were checked with a BRUEL & KJAER Sound Level Calibrator Type 4230. All readings were taken using the slow response setting.

Brian K Mark

B. K. Mark,
Asst. Transportation Design Engineer

BKM/at

cc: M. D. Grant
D. I. Harrison

Attachments (7)

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 13:40 - 15:45

STN. NAME Hamilton Service Centre

DATE: 1983-03-14

WINDS: VELOCITY 17 Km DIRECTION: Southerly TEMP: 9.3°C

GROUND CONDITIONS: Grass @ position 1,2,3,4 and 7
Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	94.0	94.0

GENERAL COMMENTS: Stroking of compressor audible at positions 3,4,5,6 and 7
Background noise consists of birds, traffic and welder working near garage

HEATER: OFF ON

PART II FLOW DATA N/A

METER ROTATION: TIME: PER REVOLUTIONS

STATIC PRESSURE: DIFFERENTIAL PRESSURE: PLATE SIZE:

FLOW: OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1	48	58	67	58	63	62	61	48	44	46	42	30	12	5	5	76
2	49															
3	53	60	70	60	65	68	56	48	44	45	39	35	22	11	5	76
4	50															
5	51															
6	53	62	71	62	69	67	66	58	51	46	43	39	23	6	5	75
7	54															
8																
9		For position #3														
10		Blowdown opened - 82 dba														
11																
12																

SIGNATURE OF TESTER

NOISE SURVEY

PART I GENERAL DATA

STN. ID.# ______ TIME: 00:00 - 01:29

STN. NAME Hamilton Service Centre DATE: 1983-03-15

WINDS: VELOCITY 17 Km DIRECTION: Westerly TEMP: 6°C

GROUND CONDITIONS: Grass @ position 1,2,3,4 and 7

Gravel @ position 5 and 6

CHECK	START	FINISH
BATTERY:	OK	OK
CALIBRATION:	93.5	94.0

GENERAL COMMENTS: Srroking of compressor audible at position 2,3,4,5, and 7

Heavy background noise from rail yard at position 6

HEATER: Flag Flapping ar possition 7 OFF ______ ON ______

PART II FLOW DATA

METER ROTATION: ______ TIME: ______ PER ______ REVOLUTIONS

STATIC PRESSURE: ______ DIFFERENTIAL PRESSURE: ______ PLATE SIZE: ______

FLOW: ______ OUTLET PIPE DIA: ______

FLOW SPEED ______ FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LI
1	48	56	64	54	58	62	57	47	47	43	38	22	12	4	5	70
2	47															
3	48	55	64	56	62	60	54	49	48	46	35	26	26	11	5	72
4	47															
5	51															
6	47	59	67	59	64	62	52	48	51	48	35	31	16	6	4	78
7	56															
8																
9		For position #3														
10		train on track - engines 74 dba														
11				- cars 54 dba												
12																

SIGNATURE OF TESTER Brian K

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 09:15 - 09:30

STN. NAME CNG Compressor Station

DATE: 1983-03-15

WINDS: VELOCITY

DIRECTION:

TEMP: 2.3°C

GROUND CONDITIONS: concrete

	START	FINISH	
CHECK BATTERY:	OK	OK	
CALIBRATION:	93.6	93.7	

GENERAL COMMENTS: Inside building

HEATER:

OFF

ON

PART II FLOW DATA

METER ROTATION:

TIME: PER REVOLUTIONS

STATIC PRESSURE:

DIFFERENTIAL PRESSURE:

PLATE SIZE:

FLOW:

OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LIN
1	82	88	86	92	66	68	72	75	77	84	77	66	63	50	34	85
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																

SIGNATURE OF TESTER Brian K. [illegible]

Memo

TO M. Grant DEPT/OFFICE Head Office DATE 1982-09-28

FROM D.I. Harrison DEPT/OFFICE G.C.E.

RE **HAMILTON S.C. NOISE LEVELS**

Current background noise levels for the Hamilton S.C. were measured Thursday, September 23, 1982 in the afternoon and at midnight. The purpose of these observations was to determine background levels prior to the installation of the C.N.G. compressor. The results of these measurements and a sketch of the area indicating the location of each observation are attached.

These observations of 48 to 52 dba afternoon and 47 to 50 dba night are the lowest background readings that can be realistically expected. Both steel plants (on opposite side of railway tracks) were shut down and there was no discernable noise coming from their directions. The only noticeable noises other than the background traffic and animal noises were the passing trains and the rooftop heating/cooling unit on the Union Gas office. Passing trains caused a peak reading of 66 dba for the engines and readings of 54 to 57 dba for the various cars when observed at position #1 (by the Union Gas sign in the front lawn). The heating/cooling unit was loud enough to be identifiable at night and was included in the position #1 night observations. As observed at position #7 this unit has a minimal effect on the readings, only one dba at this position.

The equipment used in this analysis was a BRUEL & KJAER Impulse Precision Sound Level Meter Type 2209 c/w a BRUEL & KJAER Octave Filter Set Type 1613 and calibrations were checked with a BRUEL & KJAER Sound Level Calibrator Type 4230. All readings were taken using the slow response setting.

If you have any further questions concerning the observations, interpretation of, or measurement techniques please contact me.

D.I. Harrison, P. Eng.,
Gas Control Equipment Engineer

DIH:pm

cc: D.W. McCartney

NOISE SURVEY

PART I GENERAL DATA

STN. ID.#

TIME: 23:30 - 0.35

STN. NAME Hamilton S.C.

DATE: 82-09-23/24

WINDS: VELOCITY 0 DIRECTION: 0 TEMP:

GROUND CONDITIONS: Wet grass positions 1, 2, 3, 4 & 7
Gravel positions 5 & 6

	CHECK	START		FINISH
BATTERY:		O.K.		O.K
CALIBRATION:		93.6		93.

GENERAL COMMENTS: Heating/cooling unit on top of Union's office bldg. in #1, plants in background were quiet.

HEATER: N/A OFF ON

PART II FLOW DATA N/A

ER ROTATION: TIME: PER REVOLUTIONS

STATIC PRESSURE: DIFFERENTIAL PRESSURE: PLATE SIZE:

FLOW: OUTLET PIPE DIA:

FLOW SPEED FT./SEC.

PART III NOISE MEASUREMENTS

POSITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	L
	50	58	64	57	59	60	58	49	45	41	36	31	23	5	5	
2	48															
3	47	56	63	55	57	57	57	47	44	42	34	29	19	5	5	
4	48															
5	48															
6	49	58	64	57	60	59	56	51	45	43	37	30	14	5	5	
7	47	(without roof top unit, 48 with rooftop unit)														
8																
9		For position #1														
10		train on track			- engines 66 dba											
					- cars 54 to 57 dba											

SIGNATURE OF TESTER

NOISE SURVEY

ART I GENERAL DATA

TN. ID.# ______ TIME: 14:25 - 15:45

IN. NAME Hamilton S.C. DATE: 82-09-23

NDS: VELOCITY Gusty 0-10 km DIRECTION: Variable TEMP: ______

ROUND CONDITIONS: Wet grass positions 1, 2, 3, 4 & 7
Gravel positions 5 & 6

CHECK	START	FINISH
BATTERY:	O.K.	O.K.
CALIBRATION:	93.4	93.4

GENERAL COMMENTS: CNG building partially constructed. Background noise consists of birds, traffic, dogs & crickets.

ATER: ______ OFF ______ ON ______

RT II FLOW DATA N/A

ER ROTATION: ______ TIME: ______ PER ______ REVOLUTIONS

ATIC PRESSURE: ______ DIFFERENTIAL PRESSURE: ______ PLATE SIZE: ______

OW: ______ OUTLET PIPE DIA: ______

FLOW SPEED ______ FT./SEC.

PART III NOISE MEASUREMENTS

SITIONS ARE INDICATED ON SKETCH ON REVERSE SIDE OF PAGE OR ATTACHED KEY PLAN.

	A	B	C	D	31.5	63	125	250	500	1000	2000	4000	8000	16000	31500	LIN
1	49	60	68	58	65	65	56	52	44	45	40	35	28	7	5	70
	48															
3	50	61	69	62	65	64	59	52	41	42	39	27	25	7	5	74
	50															
	51															
6	52	67	75	67	70	74	59	50	43	40	38	42	18	5	5	74
	49															
8																
10																
12																

SIGNATURE OF TESTER David K Harrison

APPENDIX 4

DRIVER'S WEEKLY FUEL RECORD

DRIVER'S WEEKLY FUEL RECORD

During the first year of the study, April 1st, 1983 to March 31st, 1984, each driver was issued a 'Driver's Weekly Fuel Record', Form #2673-1983/03.

During the week, the driver recorded fuel data and forwarded the form to the Vehicle Supervisor at the end of the week.

An explanation of each entry on the sheet is provided and a sample sheet has been filled out.

The form was replaced by Form #2673-1983/09 on April 1st, 1984 to accommodate the slow-fill facilities. A similar explanation and example are provided.

APPENDIX #4

CLARIFICATION OF TYPICAL ENTRIES

①	Jan. 1/83	DATE - Must be Given.
②	36,000	ODOMETER reading taken before vehicle leaves Company yard - Must be Given.
③	3.125	FUEL - kilograms of natural gas - Give three decimal places.
④		CHECK - 'G' for gasoline or 'N' for natural gas. This is the fuel that is used when vehicle leaves Company yard - Must be Given.
⑤	36,050	ODOMETER at switch-over - Must be Given (eg. No Fuel)
⑥	A	Switch-over code. To be filled when problems occur and shift cannot be completed on original fuel - Must be Given.
⑦	Jan. 1st	- See ①
⑧	36,075	- ODOMETER at time of fill.

NOTE: It has been assumed that 36,075 minus 36,050 kilometres has been driven on gasoline to return for fuel.

⑨	4.875	- FUEL - kilograms of natural gas - See ③.
⑩		CHECK - See ④
⑪	36,100	ODOMETER at end of shift.
⑫	Jan. 2/83	See ①
⑬	36,100	- ODOMETER reading - See ②

NOTE: When ⑪ is given ⑬ must agree with ⑪

⑭	36.1	FUEL - litres of gasoline. Given 1 decimal place.
⑮		CHECK - See ④
⑯	36,150	ODOMETER reading - See ⑤
⑰	36,160	ODOMETER at end of shift - See ⑪
⑱	B	S.W.H. codes - See ⑥
⑲	Jan. 5/83	DATE - See ⑬ and Note.
⑳	36,160	ODOMETER reading - See ②

...../2

㉑	10.000	FUEL - See ③
㉒	36,220	ODOMETER at switch-over.
㉔	36,225	ODOMETER reading at end of weekly shift.
㉕		END OF WEEKLY SHIFT - Refer to note at bottom of page and comments.

2973 - 1983/03

DRIVER'S WEEKLY FUEL RECOR

Date — From ____ To ____

Driver ____ Vehicle Number ____

Note: Completed form is to be turned in to Vehicle Supervisor at the end of the last weekly shift.

Date	Start of Shift or After Fill					End of Shift or at Switchover			FOR H.O. USE ONLY	
		Fuel		Fuel Check*						
	Odometer	Litre of G.	Kilos of N.	**G	**N	Odometer At Switchover	Odometer End of Shift	Switch-over Code	Dist. On G	Dist. On N
①	②		③		④	⑤		⑥		
⑦	⑧		⑨	⑩			⑪			
⑫	⑬	⑭			⑮	⑯	⑰	⑱		
⑲	⑳		㉑		㉒	㉓	㉔			

Switchover Codes:
A — Out of Natural Gas
B — Vehicle Problems on Natural Gas
C — Vehicle Problems other than Natural Gas
D — End of Weekly Shift
E — Other - Use Comments Below

25

Date	Comments or Problems

NOTE: Vehicle is to be operated on Natural Gas except upon return to Company yard on last weekly shift.

* Indicate type of fuel used when leaving Company yard. One (1) check per line must be given. ** G - Gasoline ** N - Natural

2073 - 1063/03

DRIVER'S WEEKLY FUEL RECORC

Date — From	To
Driver	Vehicle Number

Note: Completed form is to be turned in to Vehicle Supervisor at the end of the last weekly shift.

Date	Start of Shift or After Fill					End of Shift or at Switchover			FOR H.O. USE ONLY	
	Odometer	Fuel Litres of G.	Fuel Kilos of N.	Fuel Check* **G	Fuel Check* **N	Odometer At Switchover	Odometer End of Shift	Switchover Code	Dist. On G	Dist. On N
Jan.1/83	36,000		3.125		✓	36,050		A		
Jan.1/83	36,075		4.875	✓			36,100			
Jan.2/83	36,100	36.1			✓	36,150	36,150	B		
Jan.5/83	36,160		10.000		✓	36,220	36,225	See Belo		

Switchover Codes:
- A — Out of Natural Gas
- B — Vehicle Problems on Natural Gas
- C — Vehicle Problems other than Natural Gas
- D — End of Weekly Shift
- E — Other - Use Comments Below

Date	Comments or Problems
Jan.5/83	End of Shift.

NOTE: Vehicle is to be operated on Natural Gas except upon return to Company yard on last weekly shift.

* Indicate type of fuel used when leaving Company yard. One (1) check per line must be given. ** G - Gasoline ** N - Natural

2ND YEAR
APR. 1, 1984 TO MAR. 31, 1984
CLARIFICATION OF TYPICAL ENTRIES

①, ⑨, ⑯, ㉓, ㉙	- Apr. 1 to Apr. 5	-	Date - Must be given.
②, ⑩, ⑰, ㉔, ㉚	- 50,000 km to 50,450	-	Odometer readings taken before vehicle leaves company yard - Must be given.
③, ⑪, ⑱, ㉕, ㉚	- 2,800, 2,800, 2,800, 2,800, 800	-	Pressure readings taken on vehicle after disconnecting the natural gas slow-fill hose and before leaving company yard.
④	✓	-	Check "G" for gasoline OR "N" for natural gas. This is the fuel that is used when vehicle leaves company yard - Must be given.
⑤	- 50,150	-	Odometer at switchover to gasoline.
⑥	- 50,175	-	Odometer at end of shift.
⑦, ⑮, ㉑, ㉘, ㉟	- 400, 800, 2,800, 800, 1,000	-	Pressure readings taken on vehicle before connecting slow-fill hose to vehicle at the end of day shift.
⑧	- A	-	Out of natural gas.
⑪.	- 50	-	Fuel - litres of gasoline.
⑬.	✓	-	See ④
⑭, ⑳, ㉗, ㉞	- 50,250, 50,300, 50,450, 50,580	-	See ⑥
⑲.		-	See ④
⑳	- 50,300	-	See ⑥
㉒.	- B	-	Vehicle problems on natural gas.
㉖		-	See ④
㉛.	- 11,145	-	Fuel - natural gas dispensed and N.G. in kilograms.
㉜.			
㉝.	- 50,575	-	See ⑤

2673 1983-09

DRIVER'S WEEKLY FUEL RECOR

Date — From

To

[illegible]

Vehicle Number

Note: Completed form is to be turned in to Vehicle Supervisor at the end of the last weekly shift.

Date	Start of Shift or After Fill							End of Shift or at Switchover					FOR H O USE ONLY
	Odometer	Slow-Fill		Fuel		Fuel Check*		Odometer at Switchover	Odometer End of Shift	Slow-Fill		Switch-over Code	Dist on N
		Temp	Pressure	Litres of G	Kilos of N	**G	**N			Temp	Pressure		
Apr.1/84	50,000		2,800				✓	50,150	50,175		400	A	
Apr.2/84	50,175		2,800	50			✓		50,250		800		
Apr.3/84	50,250		2,800			✓			50,300		2,800	B	
Apr.4/84	50,300		2,800				✓		50,450		800		
Apr.5/84	50,450		800		11.145		✓	50,575	50,580		1,000	See Below	

Switchover Codes:
- A — Out of Natural Gas
- B — Vehicle Problems on Natural Gas
- C — Vehicle Problems other than Natural Gas
- D — End of Weekly Shift
- E — Other - Use Comments Below

Date	Comments or Problems
Apr.5/	End of shift.

NOTE: Vehicle is to be operated on Natural Gas except upon return to Company yard on last weekly shift.

- Indicate type of fuel used when leaving Company yard. One (1) check per line must be given.

** G - Gasoline ** N - Natural

APPENDIX 5

COMPRESSOR HYDRO COSTS

COMPRESSOR ELECTRICITY CONSUMPTION

DATE	METER READING (kwh)	CONSUMPTION (kwh x 100)
83 04 01	0042	
83 05 01	0056	14
83 06 01	0075	19
83 07 01	0091	16
83 08 01	0106	15
83 09 01	0121	15
83 10 01	0148	27
83 11 01	0155	7
83 12 01	0175	20
84 01 01	0194	19
84 02 01	0216	22
84 03 01	0232	16
84 04 01	0255	23
		213
84 05 01	0272	17
84 06 01	0285	13
84 07 01	0303	18
84 08 01	0316	13
84 09 01	0344	28
84 10 01	0353	9
84 11 01	0373	20
84 12 01	0424	51
85 01 01	0460	36
85 02 01	0485	25
85 03 01	0511	26
85 04 01	0539	28
		284

In order to calculate the compressor demand, the demand for the entire station was compared before and after the compressor installation.

Before Compressor Installation

Jan.'82	97kw
Feb.'82	122kw
Mar.'82	113kw

Aug. = 110.7kw

After Compressor Installation

Jan.'83	132kw	Jan.'84	139kw
Feb.'83	144kw	Feb.'84	139kw
Mar.'83	137kw	Mar.'84	129kw

Aug. = 136.7kw

Compressor Demand = 136.7 - 110.7

= 26kw

During the two-year study period, the hydro rates changed twice; these rates were as follows:

April 1st, 1983 to January 31st, 1984

5.38¢/kwh for 1st 100 hours
2.94¢/kwh for 2nd 100 hours
2.22¢/kwh for remainder
$2.10/kw demand

February 1st, 1984 to January 31st, 1985

5.65¢/kwh for 1st 100 hours
3.05¢/kwh for 2nd 100 hours
2.38¢/kwh for remainder
$2.20/kw demand

February 1st, 1985 to March 31st, 1985

5.750¢/kwh for 1st 100 hours
3.080¢/kwh for 2nd 100 hours
2.380¢/kwh for remainder
$2.35/kw demand

When calculating the electricity costs, the first rate applies to the first 100 hours of demand; that is, the first 100 hours x 26kw demand = 2600kwh. Since there are only five (5) months where the consumption surpassed this value, they will be calculated separately from the other months.

1) April 1st, 1983 to January 1st, 1984 (Excluding October 1983)

Energy Charge = 14700kwh x $.0538/kwh = $ 790.86
Demand Charge = 26kw/month x $2.10/kw x 9 months = 491.40

2) October 1983

Energy Charge = 1st 100 hours
2600kwh x $.0538/kwh = 139.88
= 2nd 100 hours
(2700-2600)kwh x $.0294kwh = 2.94
Demand Charge = 26kw/month x $2.10/kw = 54.60

3) February 1st, 1984 to March 1st, 1984

Energy Charge = 3900kwh x $.0565/kwh = 220.35
Demand Charge = 26kw/month x $2.20/kw x 2 months = 114.40

FIRST YEAR TOTAL ELECTRICAL COST = $1,814.43

4) April 1st, 1984 to January 1985 (Excluding Sept.'84, Dec.'84 & Jan.'85)

Energy Charge = 9000kwh x $.0565/kwh = $ 508.50
Demand Charge = 26kw/month x $2.20/kw x 6 months = 343.20

5) September 1984 and December 1984

Energy Charge = 1st 100 hours
(2600 x 2)kwh x $.0565/kwh = 293.80
= 2nd 100 hours
2700kwh x $.0305/kwh = 82.35
Demand Charge = 26kw/month x $2.20/kw x 2 months = 114.40

6) February 1985 and March 1985

Energy Charge = 5400kwh x $.0575/kwh = 310.50
Demand Charge = 26kw/month x $2.35/kw x 2 months = 122.20

7) January 1985 and March 1985

Energy Charge = 1st 100 hours
(2600 x 2)kwh x $.0575/kwh = 299.00
= 2nd 100 hours
1200kwh x $.0308/kwh = 36.96
Demand Charge = 26kw/month x $2.35/kw x 2 months = 122.20

SECOND YEAR ELECTRICITY COST = $2,233.11

TOTAL ELECTRICITY COST: - 1st Year - $1,814.43
- 2nd Year - 2,233.11
TOTAL $4,047.54

APPENDIX 6

VEHICLE MAINTENANCE DATA

TABLE 6-1-1

```
UNION GAS LTD. 2 YEAR MAINTENANCE SUMMARY
-----------------------------------------------

TOTAL TRUE N.G. MAINTENANCE COST FOR 1 YR=$8181.56
TOTAL RESEARCH AND DEVELOPMENT N.G. MAINT. COST FOR 1 YR.=$7441.73
PERCENTAGE TRUE N.G. MAINT. VS 1 YR. TOTAL MAINT.=11.12
PERCENTAGE TOTAL R. AND D. MAINT. VS 1 YR. MAINT.=9.74
PERCENTAGE TRUE MAINT. AND GASOLINE MAINT. VS 1 YR. MAINT.=90.5
TOTAL 1 YR. MAINT. COST TRUE N.G. AND R.AND D. N.G.AND GAS=$73836
TOTAL R. AND D. MAINT AND TRUE MAINT. COST 1 YR.=$15623.29
TOTAL CONTROL GROUP MAINTENANCE COST 1 YR.=$39926
```

TABLE 6-1-2

```
                 UNION GAS LTD. 2ND YEAR MAINTENANCE SUMMARY
                 -------------------------------------------

TOTAL TRUE N.G. MAINT COST FOR 1 YEAR=$3991.34
TOTAL RESEARCH AND DEVELOPMENT N.G. MAINT. COST FOR 1 YR.=$1607.65
PERCENTAGE TRUE N.G. MAINT. VS 1 YR. TOTAL MAINT.=11.61
PERCENTAGE TOTAL R. AND D. MAINT. VS 1 YR. MAINT.=4.7
PERCENTAGE TRUE MAINT. AND GASOLINE MAINT. VS 1 YR. MAINT.=95.3
TOTAL 1 YR. MAINT. COST TRUE N.G. AND R.AND D. N.G.AND GAS=$34369.82
TOTAL R. AND D. MAINT AND TRUE MAINT. COST 1 YR.=$5598.99
```

TABLE 6-1-3

```
                 UNION GAS LTD. 1ST YEAR MAINTENANCE SUMMARY
                 -------------------------------------------

TOTAL TRUE N.G. MAINTENANCE COST FOR 1 YR=$   4190.22
TOTAL RESEARCH AND DEVELOPMENT N.G. MAINT. COST FOR 1 YR.=$   5834.08
PERCENTAGE TRUE N.G. MAINT. VS 1 YR. TOTAL MAINT.=     10.62
PERCENTAGE TOTAL R. AND D. MAINT. VS 1 YR. MAINT.=     14.78
PERCENTAGE TRUE MAINT. AND GASOLINE MAINT. VS 1 YR. MAINT.=     85.69
TOTAL 1 YR. MAINT. COST TRUE N.G. AND R.AND D. N.G.AND GAS=$39467
TOTAL R. AND D. MAINT AND TRUE MAINT. COST 1 YR.=$10024.3
TOTAL CONTROL GROUP MAINTENANCE COST 1 YR.=$32716
```

TABLE 6-2-1

UNION GAS LTD. 2 YEAR NG MAINTENANCE COMPARISON

VEHICLE NUMBER	1ST YEAR TOTAL ALL MAINTENANCE	1ST YEAR TOTAL NG MAINT($)	1ST YEAR TOTAL GASOLINE MAINT($)	2ND YEAR TOTAL ALL MAINTENANCE	2ND YEAR NG TOTAL MAINT($)	2ND YEAR TOTAL GASOLINE MAINT($)
375-78	984.00	326.35	657.65	1891.00	138.01	1752.99
380-82	1899.00	362.18	1536.82	1553.00	545.58	1007.42
387-82	2387.00	602.55	1784.45	1508.00	72.40	1435.60
510-80	2684.00	414.00	2270.00	2615.00	558.73	2056.27
540-83	1220.00	383.62	836.38	784.00	258.94	525.06
650-80	1750.00	529.85	1220.15	1290.00	239.00	1051.00
762-82	2233.00	740.35	1492.65	2010.00	186.35	1823.65
773-80	1549.00	419.00	1130.00	1753.00	131.59	1621.41
778-80	1925.00	400.70	1524.30	1833.00	285.98	1547.02
779-80	1341.00	349.94	991.06	1312.00	154.12	1157.88
800-77	1116.00	364.30	751.70	1709.00	41.62	1667.38
801-83	1106.00	286.45	819.55	1068.00	193.53	874.47
814-79	1319.00	521.29	797.71	813.00	97.87	715.13
817-73	2168.00	281.90	1886.10	1424.00	55.12	1368.88
826-79	1313.00	385.60	927.40	1932.00	285.46	1646.54
862-80	633.00	144.00	489.00	1027.00	80.12	946.88
867-82	1180.00	334.85	845.15	551.00	515.55	35.45
873-80	941.00	376.85	564.15	1799.00	143.02	1655.98
876-79	1503.00	489.35	1013.65	1005.00	229.68	775.32
880-79	1874.00	252.65	1621.35	2906.00	210.01	2695.99
885-80	1559.00	369.80	1189.20	1181.00	269.62	911.38
887-77	1621.00	252.35	1368.65	2784.00	153.62	2630.38
892-77	1835.00	374.85	1460.15	1627.00	248.53	1378.47
896-78	1821.00	562.02	1258.98	1204.00	107.24	1096.76
898-80	1506.00	314.00	1192.00	1394.00	354.49	1039.51
TOTAL	39467.00	9838.80	29628.20	38973.00	5556.18	33416.82

TABLE 6-2-2

1ST YEAR NG MAINTENANCE COMPARISON

VEHICLE NUMBER	1ST YEAR TOTAL ALL MAINTENANCE	1ST YEAR TOTAL NG MAINT($)	1ST YEAR TOTAL GASOLINE MAINT($)	CONTROL GROUP MAINTENANCE COST
375-78	984.00	326.35	657.65	1323.00
380-82	1899.00	362.18	1536.82	526.00
387-82	2387.00	602.55	1784.45	1620.00
510-80	2684.00	414.00	2270.00	2620.00
540-83	1220.00	383.62	836.38	673.00
650-80	1750.00	529.85	1220.15	2309.00
762-82	2233.00	740.35	1492.65	754.00
773-80	1549.00	419.00	1130.00	1244.00
778-80	1925.00	400.70	1524.30	1258.00
779-80	1341.00	349.94	991.06	572.00
800-77	1116.00	364.30	751.70	680.00
801-83	1106.00	286.45	819.55	813.00
814-79	1319.00	521.29	797.71	1194.00
817-78	2168.00	281.90	1886.10	939.00
826-79	1313.00	385.60	927.40	2068.00
862-80	633.00	144.00	489.00	949.00
867-82	1180.00	334.85	845.15	628.00
873-80	941.00	376.85	564.15	657.00
876-79	1503.00	489.35	1013.65	2328.00
880-79	1874.00	252.65	1621.35	1282.00
885-80	1559.00	369.80	1189.20	1065.00
887-77	1621.00	252.35	1368.65	2400.00
892-77	1835.00	374.85	1460.15	1137.00
896-78	1821.00	562.02	1258.98	897.00
898-80	1506.00	314.00	1192.00	2780.00
TOTAL	39467.00	9838.80	29628.20	32716.00

UNION GAS LTD. 2 YEAR MAINTENANCE REPORT #1

VEHICLE NUMBER	LEAK LABOUR	SETUP	OIL PROBE	TIMING ADJUST ADVANCE	VALVES OR FITTINGS	FILTER AND GASKET	MISC LABOUR	NO. OF CHANGES IN 2 YR.
375-78	25.37	18.75	79.35	16.00	85.35	19.65	84.12	5
380-82	8.00	50.75	75.53	24.00	125.35	66.52		6
387-72	8.00	88.00		31.35	24.60		40.95	7
510-80	17.37	28.12	56.00	8.00	48.00	19.65	37.50	7
540-83		56.25			123.35	29.00	9.37	8
650-80	44.12	18.75	44.35		48.00			6
762-82		61.62	23.35	20.00	82.20	19.65		7
773-80		41.49		8.00	109.35	19.65		9
778-80			23.35		142.72	19.50		6
779-80	56.25		23.35	8.00	125.35			6
800-77		9.37	16.10					6
801-83		9.37		9.37	44.80	44.80		5
814-79			28.35	18.79	97.00	19.65		6
817-78		40.00		24.00				7
826-79	47.80	23.43	31.35		200.85			7
862-80		16.00	27.35			19.65		8
867-82	8.00	32.00		32.00			28.12	5
873-80	34.75	16.00	23.35	32.00	137.30			5
876-79	48.03	28.12	36.35		121.35	19.65		6
880-79	32.00	9.37	67.00			19.65		4
885-80			24.50	16.00	17.00			12
887-77		16.00	24.50	38.95				6
892-77		34.75	47.35		80.00	19.65		6
896-78		16.00	33.48	16.00		19.65		6
898-80		53.50	44.35		87.56	38.40		5
OTAL	329.69	667.64	729.31	302.46	1700.13	394.72	200.06	161

TABLE 6-3-2

UNION GAS LTD. 2 YEAR MAINTENANCE REPORT #2

VEHICLE NUMBER	PRIME BUTTON FREE-UP	REFILL HOSE REPAIR	REGULATOR	MIXER	COPPER PLUGS	SOLENOID N.G.	FILL PROBE	TEMP FREEZE UP
375-78							40.15	
380-82	57.02	8.75	155.70			77.87	22.93	
387-72			157.00	98.40			64.15	
510-80			209.62			56.91	176.22	17.37
540-83				37.50			124.07	
650-80			66.75				18.75	9.37
762-82			53.50			28.12	100.00	
773-80	8.00		34.46				145.60	8.00
778-80							168.12	
779-80			8.00	18.75	17.54	18.75	78.75	
800-77							147.10	
801-83				22.60			128.35	
814-79			68.12			126.00	27.75	
817-78	28.12						56.00	
826-79			23.56	18.75			142.52	
862-80						53.12		
867-82			36.50			18.77	175.70	
873-80	18.75		18.75				77.07	
876-79						89.04	88.00	28.12
880-79			65.62	78.75		18.75	24.00	
885-80	37.50					66.75	200.72	
887-77			83.87				141.10	18.75
892-77			205.75				138.88	
896-78		9.37	34.75			16.00	193.12	
898-80			22.40			18.75	100.00	
OTAL	149.39	18.12	1244.35	274.75	17.54	588.83	2579.05	81.61

TABLE 6-3-3

UNION GAS LTD. 2 YEAR MAINTENANCE REPORT #3

VEHICLE NUMBER	GAUGES	FILL PROBE CLEAN	CONTROL MODULE	MEASURING EQUIPMENT	IGNITION SYSTEM	PRESS TEMP GAUGES	VACCUM HOSE	N.G. FUSES
375-78							28.12	
380-82			194.12				28.12	
387-72								
510-80			178.35				25.12	
540-83	107.77	8.00			18.75		20.00	
650-80	113.08	26.75	213.00	85.00				
762-82	11.65	41.37	218.24		164.50			
773-80		52.72					9.37	
778-80		52.12	265.12			16.00	18.75	
779-80		44.12				24.00		
800-77		136.65	16.00					
801-83	88.37	81.50					28.12	
814-79	115.00				37.50			
817-78	69.40							
826-79	64.55	18.75					16.00	9.00
862-80						8.00		
867-82	128.00		272.62					
873-80	107.65		18.75					
876-79		9.37						
880-79	60.15	17.37				170.00		
885-80			32.00					
887-77		34.75						
892-77								
896-78		18.75	228.39					
898-80	217.28	18.75				18.75		
OTAL	1082.90	560.97	1636.59	85.00	220.75	236.75	173.60	9.00

TABLE 6-3-4

UNION GAS LTD. 2 YEAR MAINTENANCE REPORT #4

VEHICLE NUMBER	MODEL	USEAGE	N.G. TANKS	TOTAL OIL($) ANALYSIS	2 YEAR TOTAL ALL MAINTENANCE N.G. VEH
375-78	B-200	STORES	138.01	67.50	2875.00
380-82	ESCORT	LOCATE	545.58	81.00	3452.00
387-72	CIERA	R.PARKER	72.40	94.50	3895.00
510-80	D-300	C/S	558.73	94.50	5299.00
540-83	RANGER	C/S	258.94	108.00	2004.00
650-80	F-350	GAS MEAS.	239.00	81.00	3040.00
762-82	W-150	PLANT MAIN	186.35	94.50	4243.00
773-80	B-200	C/S	131.59	121.50	3302.00
778-80	E-150	C/S	285.98	81.00	3758.00
779-80	HORIZON	LEAK SURV.	154.12	81.00	2653.00
800-77	B-200	C/S	41.62	81.00	2825.00
801-83	RANGER	C/S	193.53	67.50	2174.00
814-79	E-150	C/S	97.87	81.00	2132.00
817-78	B-200	C/S	55.12	94.50	3592.00
826-79	E-150	C/S	285.46	94.50	3245.00
862-80	LAURENTIAN	GAS MEAS.	80.12	108.00	1660.00
867-82	ESCORT	LOCATE	591.05	67.50	1731.00
873-80	B-200	C/S	190.02	67.50	2740.00
876-79	D-300	D/M	292.68	81.00	2508.00
880-79	LN-800	D/M	210.01	54.00	4709.00
885-80	B-200	C/S	269.62	162.00	2740.00
887-77	D-300	D/M	153.62	81.00	4405.00
892-77	D-300	D/M	248.53	81.00	3447.00
896-78	D-300	D/M	107.24	81.00	3025.00
898-80	D-300	D/M	354.49	67.50	2900.00
OTAL			5741.68	2173.50	78354.00

TABLE 6-4-1

UNION GAS LTD. 2ND YEAR MAINTENANCE REPORT #1

VEHICLE NUMBER	LEAK LABOUR	SETUP	OIL PROBE	TIMING ADJUST ADVANCE	VALVES OR FITTINGS	FILTER AND GASKET	MISC. LABOUR	NO. OF OIL SAMPLES
375-78	9.37	18.75					28.12	1
380-82		18.75				46.87		3
387-82							18.75	1
510-80	9.37	28.12					37.50	2
540-83		56.25					9.37	4
650-80	28.12	18.75						1
762-82		28.12						2
773-80		18.75						3
778-80					9.37			1
779-80	56.25							1
800-77		9.37						1
801-83		9.37		9.37		44.80		1
814-79								1
817-78								2
826-79	23.80	23.43			42.00			2
862-80								2
867-82						31.37	28.12	1
873-80	18.75				19.95			2
876-79	48.03	28.12						2
880-79		9.37						
885-80								6
887-77								1
892-77		18.75						1
896-78								1
898-80		37.50			23.56	18.75		1
TOTAL	193.69	323.40		9.37	94.88	142.19	121.86	43

TABLE 6-4-2

UNION GAS LTD. 2ND YEAR MAINTENANCE REPORT #2

VEHICLE NUMBER	PRIME BUTTON FREE-UP	REFILL HOSE REPAIR	REGULATOR	MIXER	COPPER PLUGS	SOLENOID NG	FILL PROBE	TEMP FREEZE-UP
375-78							40.15	
380-82	30.62		153.70			9.87	22.93	
387-82							40.15	
510-80			177.62			56.91	9.37	9.37
540-83				37.50			63.07	
650-80			18.75				18.75	9.37
762-82			37.50			28.12		
773-80							53.60	
778-80							28.12	
779-80				18.75		18.75	18.75	
800-77							18.75	
801-83								
814-79			28.12				18.75	
817-78	28.12							
826-79			23.56	18.75			78.52	
862-80						53.12		
867-82						18.77	30.77	
873-80	18.75		18.75				21.07	
876-79						89.04		28.12
880-79			65.62	78.75		18.75		
885-80	37.50					66.75	84.37	
887-77			83.87				18.75	18.75
892-77			205.75				10.53	
896-78		9.37	18.75				28.12	
898-80			22.40			18.75		
TOTAL	114.99	9.37	854.39	153.75		378.83	604.52	65.61

TABLE 6-4-3

UNION GAS LTD. 2ND YEAR MAINTENANCE REPORT #3

VEHICLE NUMBER	GAUGES	FILL PROBE CLEAN	CONTROL MODULE	MEASURING EQUIPMENT	IGNITION SYSTEM	PRESS TEMP GAUGES	VACUUM HOSE	NG FUSES
375-78							28.12	
380-82			194.22				28.12	
387-82								
510-80			178.35				25.12	
540-83					18.75		20.00	
650-80	113.01	18.75						
762-82		9.37	56.24					
773-80		9.37					9.37	
778-80		28.12	188.12				18.75	
779-80		28.12						
800-77								
801-83	88.37						28.12	
814-79					37.50			
817-78								
826-79	29.65	18.75						
862-80								
867-82	120.00		272.62					
873-80			18.75					
876-79		9.37						
880-79	28.15	9.37						
885-80								
887-77		18.75						
892-77								
896-78		18.75				18.75		
898-80	201.28	18.75						
TOTAL	580.46	187.47	908.30		56.25	18.75	157.60	

TABLE 6-4-4

UNION GAS LTD. 2ND YEAR MAINTENANCE REPORT #4

VEHICLE NUMBER	MODEL	USAGE	NG TANKS	TOTAL NG MAINT($)	2ND YEAR NG TOTAL MAINT($)
375-78	B-200	STORES		13.50	138.01
380-82	ESCORT	LOCATE		40.50	545.58
387-82	CIERA	R.PARKER		13.50	72.40
510-80	D-300	C/S		27.00	558.73
540-83	RANGER	C/S		54.00	258.94
650-80	F-350	GAS MEAS.		13.50	239.00
762-82	W-150	PLANT MAIN		27.00	186.35
773-80	B-200	C/S		40.50	131.59
778-80	E-150	C/S		13.50	285.98
779-80	HORIZON	LEAK SURV.		13.50	154.12
800-77	B-200	C/S		13.50	41.62
801-83	RANGER	C/S		13.50	193.53
814-79	E-150	C/S		13.50	97.87
817-78	B-200	C/S		27.00	55.12
826-79	E-150	C/S		27.00	285.46
862-80	LAURENTIAN	GAS MEAS.		27.00	80.12
867-82	ESCORT	LOCATE		13.50	515.55
873-80	B-200	C/S		27.00	143.02
876-79	D-300	D/M		27.00	229.68
880-79	LN-800	D/M			210.01
885-80	B-200	C/S		81.00	269.62
887-77	D-300	D/M		13.50	153.62
892-77	D-300	D/M		13.50	248.53
896-78	D-300	D/M		13.50	107.24
898-80	D-300	D/M		13.50	354.49
TOTAL				580.50	5556.18

TABLE 6-5-1

UNION GAS LTD. 1ST YEAR NG MAINTENANCE REPORT #1

VEHICLE NUMBER	LEAK LABOUR	SETUP	OIL PROBE	TIMING ADJUST ADVANCE	VALVES OR FITTINGS	FILTER AND GASKET	MISC. LABOUR	NO. OF OIL SAMPLES
375-78	16.00		79.35	16.00	85.35	19.65	56.00	4
380-82	8.00	32.00	75.53	24.00	125.35	19.65		3
387-82	8.00	88.00		31.35	24.60		22.20	6
510-80	8.00		56.00	8.00	48.00	19.65		5
540-83					123.35	29.00		4
650-80	16.00		44.35		48.00			5
762-82		33.50	23.35	20.00	82.20	19.65		5
773-80		23.19		8.00	109.35	19.65		6
778-80			23.35		133.35	19.50		5
779-80			23.35	8.00	125.35			5
800-77			16.10					5
801-83								4
814-79			28.35	18.79	97.00	19.65		5
817-78		40.00		24.00				5
826-79	24.00		31.35		155.85			5
862-80		16.00	27.35			19.65		6
867-82	8.00	32.00		32.00		19.65		4
873-80	16.00	16.00	23.35		117.35			3
876-79			36.35		121.35	19.65		4
880-79	32.00		67.00	16.00		19.65		4
885-80			24.50	38.95	17.00			6
887-77		16.00	24.50					5
892-77		16.00	47.35	16.00	80.00	19.65		5
896-78		16.00	33.48			19.65		5
898-80		16.00	44.35		64.00	19.65		4
TOTAL	136.00	344.69	729.31	261.09	1557.45	303.95	78.20	118

UNION GAS LTD. 1ST YEAR NG MAINTENANCE REPORT #2

VEHICLE NUMBER	PRIME BUTTON FREE-UP	REFILL HOSE REPAIR	REGULATOR	MIXER	COPPER PLUGS	SOLENOID NG	FILL PROBE	TEMP FREEZE-UP
375-78								
380-82	26.40	8.75	2.00					
387-82			157.00	98.40		68.00	24.00	
510-80			32.00				166.85	8.00
540-83							61.50	
650-80			48.00					
762-82			16.00				100.00	8.00
773-80	8.00		34.46				92.00	
778-80							40.00	
779-80			8.00		17.54		60.20	
800-77							128.35	
801-83				22.60			128.35	
814-79			40.00			126.00	9.00	
817-78							56.00	
826-79							64.00	
862-80								
867-82			36.50				144.70	
873-80							56.00	
876-79							88.00	
880-79							24.00	
885-80							176.35	
887-77							128.35	
892-77							128.35	
896-78			16.00			16.00	165.00	
898-80							100.00	
TOTAL	34.40	8.75	389.96	121.00	17.54	210.00	1941.00	16.00

TABLE 6-5-3

UNION GAS LTD. 1ST YEAR NG MAINTENANCE REPORT #3

VEHICLE NUMBER	GAUGES	FILL PROBE CLEAN	CONTROL MODULE	MEASURING EQUIPMENT	IGNITION SYSTEM	PRESS TEMP GAUGES	VACUUM HOSE	NG FUSES
375-78								
380-82								
387-82								
510-80								
540-83	107.77	8.00						
650-80		8.00	213.00	85.00				
762-82	11.65	32.00	162.00		164.50			
773-80		43.35						
778-80		24.00	77.00			16.00		
779-80		16.00				24.00		
800-77		136.35	16.00					
801-83		81.50						
814-79	115.00							
817-78	69.40						16.00	9.00
826-79	34.90					8.00		
862-80								
867-82	8.00							
873-80	107.65							
876-79						170.00		
880-79	32.00	8.00						
885-80			32.00					
887-77		16.00						
892-77								
896-78			228.39					
898-80	16.00							
TOTAL	502.37	373.20	728.39	85.00	164.50	218.00	16.00	9.00

TABLE 6-5-4

UNION GAS LTD. 1ST YEAR NG MAINTENANCE REPORT #4

VEHICLE NUMBER	MODEL	USAGE	NG TANKS	TOTAL OIL ($) ANALYSIS	1ST YEAR NG TOTAL MAINT($)
375-78	B-200	STORES		54.00	326.35
380-82	ESCORT	LOCARE		40.50	362.18
387-82	CIERA	R. PARKER		81.00	602.55
510-80	D-300	C/S		67.50	414.00
540-83	RANGER	C/S		54.00	383.62
650-80	F-350	GAS MEAS.		67.50	529.85
762-82	W-150	PLANT MAIN		67.50	740.35
773-80	B-200	C/S		81.00	419.00
778-80	E-150	C/S		67.50	400.70
779-80	HORIZON	LEAK SURV.		67.50	349.94
800-77	B-200	C/S		67.50	364.30
801-83	RANGER	C/S		54.00	286.45
814-79	E-150	C/S		67.50	521.29
817-78	B-200	C/S		67.50	281.90
826-79	E-150	C/S		67.50	385.60
862-80	LAURENTIAN	GAS MEAS.		81.00	144.00
867-82	ESCORT	LOCATE	75.50	54.00	334.85
873-80	B-200	C/S	47.00	40.50	376.85
876-79	D-300	D/M	63.00	54.00	489.35
880-79	LN-800	D/M		54.00	252.65
885-80	B-200	C/S		81.00	369.80
887-77	D-300	D/M		67.50	252.35
892-77	D-300	D/M		67.50	374.85
896-78	D-300	D/M		67.50	562.02
898-80	D-300	D/M		54.00	314.00
TOTAL			185.50	1593.00	9838.80

APPENDIX 7

FUEL ECONOMY

ALL SAMPLE CALCULATIONS PROVIDED IN THIS
APPENDIX ARE PERFORMED ON DATA COLLECTED
FROM VEHICLE #762-82 IN THE FIRST YEAR
OF STUDY UNLESS INDICATED OTHERWISE

For ease of comparison and analysis, the twenty-five (25) vehicles in this study have been broken up into five (5) basic groups. The vehicles included in each group are listed below:

GROUP A
(Escort,Ciera,Laurentian)
#380-82
#387-82
#779-80
#862-80
#867-82

GROUP B
(Long and Short Body Vans)
#773-80
#778-80
#800-77
#814-77
#817-78
#826-79
#873-80
#885-80

GROUP C
(Utility & 4-Wheel Drive Vehicles)
#510-80
#650-80
#762-82
#887-77
#892-77
#898-80

GROUP D
(Ford Rangers)

#540-83
#801-83

GROUP E
(Dump Truck)

#880-79

SAMPLE CALCULATIONS FOR TABLES 7-1-1 TO 7-1-3

Included in these tables is the number of kilometres driven on natural gas and gasoline by each vehicle along with the amount of each fuel consumed.

The column titled 'Equiv L Gasoline' contains data that indicates the number of litres of gasoline required to provide the same number of btu's consumed by the vehicle on natural gas and is calculated as follows:

Gasoline Fuel Consumption
Base (B.C. L/100km) = 21.3L/100km TABLE 7-2-3

NG Kilograms = 3802.232kg)
) TABLE 7-3-3
NG Kilometres = 28783kg)

$$\text{NG Fuel Consumption} = \frac{3802.232\text{kg}}{28783\text{km}}$$

$$= .1321\text{kg/km}$$

$$\text{NG Kilograms/L} = \frac{0.1321\text{kg/km}}{.213\text{L/km}}$$

$$= .620\text{kg/L}$$

$$\text{Equivalency Factor} = \frac{1}{.620} = 1.6129\text{L/kg}$$

$$\text{Equiv L of Gasoline} = 3802.232\text{kg} \times 1.6129\text{L/kg}$$

$$= 6133 \text{ Litres}$$

The final column 'Utilization' is an indication of the percentage of the time that the vehicle is being run on natural gas and is calculated as follows:

FROM TABLE 7-1-3 - Vehicle #762-82

NG Kilometres = 28783
Gasoline Kilometres = 2325

$$\text{Utilization} = \frac{\text{NG km}}{\text{NG km + Gasoline km}} \times 100\%$$

$$= \frac{28783}{28783 + 2325} \times 100$$

$$= 92.5\%$$

TABLE 7-1-1

```
                   UNION GAS LTD. 2 YEAR N.G. SUMMAPY REPORT

           NATURAL      TOTAL     NATURAL                  TOTAL    UTILIZATI
  VEHICLE    GAS      GASOLINE      GAS      N.G. EQUIV  GASOLINE NG/NG + G
  NUMBER  KILOMETERS KILOMETERS KILOGRAMS L. GASOLINE   LITRES   KILOMETER
  ------- ---------- ---------- --------- -----------  --------  ---------
  375-78        8335       8257   703.799    1875.375      2008         50
  380-82       43011       9143  2602.420    4043.034      1398         82
  387-72       16787      50204  1224.141    1930.505      6140         25
  510-80       48513      10332 10729.243   18386.427      4435         82
  540-83       21664       4734  2434.379    4116.160      1216         82
  650-80       16131       3680  4137.566    7355.736      1024         81
  762-82       56176       6412  7175.811   11965.488      2363         89
  773-80       17961       2681  2541.476    4041.225       717         87
  778-80       11721       2784  2346.431    2789.598       601         80
  779-80       15553       4550  1072.714    1990.784       341         77
  800-77       24886       2203  3525.641    6271.272       434         91
  801-83       17264       3356  2275.821    3280.160       967         83
  814-79       18627       2583  3028.806    5979.267       693         87
  817-78       17979       1753  2480.654    4620.603       631         91
  826-79       19237       3976  2947.448    5097.805       819         82
  862-80       29940       4018  2761.153    4580.820       649         88
  867-82       47294       5933  3097.697    5627.986       745         88
  873-80       18408       7982  2202.290    3700.008       745         69
  876-79        8378        888  2635.107    3326.066       522         90
  880-79       17461       5666  7003.621   12798.913      5139         75
  885-80       21116       4580  2102.473    4307.664       906         82
  887-77       19589       3459  4824.006    8246.969      1258         85
  892-77       12291       1523  4071.850    7325.436       462         89
  896-78        2049       3514  1371.815    1428.153      1346         36
  898-80        4089       3936  1052.575    1537.464      1177         51
          ---------- ---------- --------- -----------  --------
TOTAL         534460     158147 80348.937  136622.918     36736
          ========== ========== ========= ===========  ========




TOTAL ESTIMATED COST TO OPERATE VEHICLE ON GASOLINE =$47612.91
TOTAL ELECTRICAL COST (METERED)=$2047.54
TOTAL COST NATURAL GAS (DISPENSED)=$22536.7
TWO (2) YEAR SAVINGS (COMPARED TO VEHICLE OPERATED ON GASOLINE  ONLY)=$2507
AVERAGE L 100 KM ON GASOLINE=23.23
AVERAGE L 100 KM ON N.G.=22.02
N.G. UTILIZATION=77.3
COMPRESSOR HOURS=2120
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UNION GAS LTD. 2ND YEAR REPORT ENDING 85-03-31

VEHICLE NUMBER	NATURAL GAS KILOMETERS	GASOLINE KILOMETERS	NATURAL GAS KILOGRAMS	N.G. EQUIV L GASOLINE	GASOLINE LITRES	UTILIZATIO NG/NG + GA KILOMETERS
375-78	1950	7191	7.856	438.750	1759	21.
380-82	20208	5422	1091.752	1899.552	1023	78.
387-72	6699	21628	499.832	770.385	2658	23.
510-80	21832	5186	4443.180	8274.328	2901	80.
540-83	9513	2926	1059.820	1807.470	565	76.
650-80	7958	567	2036.413	3628.848	116	93.
762-82	27393	4087	3373.579	5834.709	1513	87.
773-80	9195	974	1327.112	2068.875	309	90.
778-80	6465	1578	1220.255	1538.670	281	80.
779-80	7476	1658	510.306	956.928	146	81.
800-77	11782	1124	1760.523	2969.064	88	91.
801-83	8856	1403	1170.977	1682.640	377	86.
814-79	8826	1393	1457.100	2833.146	112	86.
817-78	8177	675	1141.129	2101.489	337	92.
826-79	9678	1501	1354.030	2564.670	233	86.
862-80	13866	1484	1284.676	2121.498	191	90.
867-82	23337	2690	1489.961	2777.103	424	89.
873-80	5118	1684	657.687	1028.718	181	75.
876-79	3446	482	1021.578	1368.062	129	87.
880-79	6670	3300	2312.197	4889.110	2448	66.
885-80	10093	1985	990.125	2058.972	202	83.
887-77	9588	1894	2272.786	4036.548	682	83.
892-77	5539	713	1687.416	3301.244	184	88.
896-78	558	2734	355.601	388.926	951	17.
898-80	573	2274	195.597	215.448	674	20.
TOTAL	244796	76553	34721.488	61555.153	18484	

TOTAL ESTIMATED COST TO OPERATE VEHICLE ON GASOLINE =$22381.47
TOTAL ELECTRICAL COST (METERED)=$[illegible]
TOTAL COST NATURAL GAS (DISPENSED)=$9374.8
YEARLY SAVINGS (COMPARED TO VEHICLE OPERATED ON GASOLINE ONLY)=$13006.67
AVERAGE L 100 KM ON GASOLINE=24.14
AVERAGE L 100 KM ON N.G.=20.78
N.G. UTILIZATION=74.38
COMPRESSOR HOURS=1423

TABLE 7-1-3

```
                  UNION GAS LTD. 1ST YEAR REPORT ENDING 84-03-31.
           NATURAL                  NATURAL                                         UTILIZATIO
VEHICLE      GAS       GASOLINE       GAS        N.G. EQUIV      GASOLINE    NG/NG + GA
NUMBER  KILOMETERS KILOMETERS KILOGRAMS    L GASOLINE       LITRES     KILOMETERS
------- ---------- ---------- ---------- -------------- ---------- ----------
375-78        6385       1066    695.943       1436.625        249         85.
380-82       22803       3721   1510.668       2143.482        375         84.
387-82       10088      28576    724.309       1160.120       3482         24.
510-80       26681       5146   6286.063      10112.099       1534         82.
540-83       12151       1808   1374.559       2308.690        651         85.
650-80        8173       3113   2101.153       3726.888        908         71.
762-82       28783       2325   3802.232       6130.779        850         91.
773-80        8766       1707   1214.364       1972.350        408         82.
778-80        5256       1206   1126.176       1250.928        320         79.
779-80        8077       2892    562.408       1033.856        195         72.
800-77       13104       1079   1765.118       3302.208        346         91.
801-83        8408       1953   1104.844       1597.520        590         79.
814-79        9801       1190   1571.706       3146.121        581         87.
817-78        9802       1078   1339.525       2519.114        294         89.
826-79        9559       2475   1593.418       2533.135        586         78.
862-80       16074       2534   1476.477       2459.322        458         84.
867-82       23957       3243   1607.736       2850.883        321         87.
873-80       13290       6298   1544.603       2671.290        564         67.
876-79        4932        406   1613.529       1958.004        393         92.
880-79       10791       2366   4691.424       7909.803       2691         79.
885-80       11023       2595   1112.348       2248.692        704         79.
887-77       10001       1565   2551.220       4210.421        576         85.
892-77        6752        810   2384.434       4024.192        278         88.
896-78        1491        780   1016.214       1039.227        395         65.
898-80        3516       1662    856.978       1322.016        503         67.
        ---------- ---------- ---------- -------------- ----------
TOTAL       289664      81594  45627.449      75067.765      18252
        ========== ========== ========== ============== ==========
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TOTAL ESTIMATED COST TO OPERATE VEHICLE ON GASOLINE =$25231.44
TOTAL ELECTRICAL COST (METERED)=$1814.43
TOTAL COST NATURAL GAS (DISPENSED)=$13161.9
YEARLY SAVINGS (COMPARED TO VEHICLE OPERATED ON GASOLINE ONLY)=$12069.54
AVERAGE L 100 KM ON GASOLINE=22.4
AVERAGE L 100 KM ON N.G.=23.07
TOTAL N.G. UTILIZATION=78.8  (UTILIZATION WITHOUT 387-82 IS 81.1%)
COMPRESSOR HOURS=688
```

SAMPLE CALCULATIONS FOR TABLES 7-2-1 TO 7-2-3

The fourth column titled 'L.S.C. (Life Since Conversion) Gasoline L/100km' is an indication of the mileage (litres used per 100km) of the vehicle when operated on gasoline since its conversion to a dual fuel vehicle.

e.g. Total Litres of Gasoline = 850 TABLE 7-2-3
Total Kilometres driven on Gasoline = 2325

$$\text{L.S.C. Gasoline L/100km} = \frac{850}{2325} \times 100$$

$$= 36.56 \text{ L/100km}$$

Conversely, the next column 'B.C. (Before Conversion) Gasoline L/100km' is a similar indication of the gasoline mileage prior to the vehicles conversion. The numbers were calculated from vehicle data kept prior to the conversion date.

Cost to operate is based on the gasoline price for that year.

e.g. Gasoline Price = $.37/L TABLE 7-2-3
Gasoline Litres = 850 Litres

$$\text{Cost to Operate} = 850 \times 0.37$$

$$= \$314.50$$

To allow for comparison of the operating cost, it is converted to a cost per kilometre.

Cost to Operate = $314.50 TABLE 7-2-3
Gasoline Kilometres = 2325

$$\text{Operating Cost - Gasoline Cents/km (\$.37/L)} = \frac{\$314.50}{2325} \times 100$$

$$= 13.53¢/\text{km}$$

Since the price of gasoline was different over the two-year study period, the cost per kilometre for the two (2) combined years (TABLE 7-2-1) is a weighted average of the two (2) years based on the number of kilometres driven each year.

1st Year km = 2325km)
1st Year ¢/km = 13.53¢/km) TABLE 7-2-3

2nd Year km =)
2nd Year ¢/km = 14.99¢/km) TABLE 7-2-2

$$\text{2-Year Cost/km} = \frac{(2325)(13.53) + (4087)(14.99)}{2325 + 4087}$$

$$= 14.46¢/\text{km}$$ TABLE 7-2-1

TABLE 7-2-1

UNION GAS LTD. 2 YEAR GASOLINE OPERATING DATA

VEHICLE NUMBER	TOTAL GASOLINE LITRES	TOTAL GASOLINE KILOMETRES	GASOLINE L/100 km	BEFORE CONVERSION L/100 km	TOTAL COST TO OPERATE	AVERAGE /km
375-78	2008	8257	24.32	22.5	804.53	9.74
380-82	1398	9143	15.29	9.4	553.07	6.04
387-82	6140	50204	12.23	11.5	2364.83	4.71
510-80	4435	10332	42.92	37.9	1742.49	16.84
540-83	1216	4734	25.69	19.0	469.70	9.92
650-80	1024	3680	27.83	45.6	382.94	10.40
762-82	2363	6412	36.85	21.3	927.77	14.46
773-80	717	2681	26.74	22.5	276.11	10.29
778-80	601	2784	21.59	23.8	232.21	8.34
779-80	341	4550	7.49	12.8	131.28	2.88
800-77	434	2203	19.70	25.2	163.66	7.42
801-83	967	3356	28.81	19.0	370.99	11.03
814-79	693	2583	26.83	32.1	260.33	10.08
817-78	631	1753	35.99	25.7	245.27	13.99
826-79	819	3976	20.59	26.5	311.19	7.83
862-80	649	4018	16.15	15.3	246.82	6.14
867-82	745	5933	12.56	11.9	290.49	4.89
873-80	745	7982	9.33	20.1	281.99	3.52
876-79	522	888	58.78	39.7	197.66	22.26
880-79	5139	5666	90.69	73.3	1987.11	35.07
885-80	906	4580	19.78	20.4	342.29	7.47
887-77	1258	3459	36.37	42.1	489.33	14.14
892-77	462	1523	30.33	59.6	177.38	11.65
896-78	1346	3514	38.30	69.7	531.31	15.12
898-80	1477	3936	29.90	37.6	459.08	11.66
TOTAL	36736	158147			14239.83	

TABLE 7-2-2

UNION GAS LTD. 2ND YEAR GASOLINE OPERATING DATA

VEHICLE NUMBER	GASOLINE LITRES	GASOLINE KILOMETRES	GASOLINE L/100 km	BEFORE CONVERSION L/100 km	COST TO OPERATE AT 0.37/L	OPERATING COST GAS /km AT 0.405/L
375-78	1759	7191	24.46	22.5	712.40	9.91
380-82	1023	5422	18.87	9.4	414.32	7.64
387-82	2658	21628	12.25	11.5	1076.45	4.98
510-80	2901	5186	55.94	37.9	1174.91	22.66
540-83	565	2926	19.31	19.0	228.83	7.82
650-80	116	567	20.46	45.6	46.78	8.29
762-82	1513	4087	37.02	21.3	612.77	14.99
773-80	309	974	31.72	22.5	125.15	12.85
778-80	281	1578	17.81	23.8	113.81	7.21
779-80	146	1658	8.81	12.8	59.13	3.57
800-77	88	1124	7.83	25.2	35.64	3.17
801-83	377	1403	26.87	19.0	152.69	10.88
814-79	112	1393	8.04	32.1	45.37	3.26
817-78	337	675	49.93	25.7	136.49	20.22
826-79	233	1501	15.52	26.5	94.37	6.29
862-80	191	1484	12.87	15.3	77.36	5.21
867-82	424	2690	15.76	11.9	171.72	6.38
873-80	181	1684	10.75	20.1	73.31	4.35
876-79	129	482	26.76	39.7	52.25	10.84
880-79	2448	3300	74.18	73.3	991.44	30.04
885-80	202	1985	10.18	20.4	81.81	4.12
887-77	682	1894	36.01	42.1	276.21	14.58
892-77	184	713	25.81	59.6	74.52	10.45
896-78	951	2734	31.76	69.7	385.16	14.09
898-80	674	2274	29.64	37.6	272.97	12.00
TOTAL	18484	76553			7485.85	

TABLE 7-2-3

UNION GAS LTD. 1ST YEAR GASOLINE OPERATING DATA

VEHICLE NUMBER	LIFE SINCE CONVERSION GAS (L)	LIFE SINCE CONVERSION GAS (km)	LIFE SINCE CONVERSION L/100 km GAS	BEFORE CONVERSION L/100 km GASOLINE	COST TO OPERATE GASOLINE AT 0.37/L	OPERATING COST GAS /km AT 0.37/L
375-78	249	1066	23.36	22.5	92.13	8.64
380-82	375	3721	10.08	9.4	138.75	3.73
387-82	3482	28576	12.19	11.5	1288.34	4.51
510-80	1534	5146	29.81	37.9	567.58	11.03
540-83	651	1808	36.01	19.0	240.87	13.32
650-80	908	3113	29.17	45.6	335.96	10.79
762-82	850	2325	36.56	21.3	314.50	13.53
773-80	408	1707	23.90	22.5	150.96	8.84
778-80	320	1206	26.53	23.8	118.40	9.82
779-80	195	2892	6.74	12.8	72.15	2.49
800-77	346	1079	32.07	25.2	128.02	11.86
801-83	590	1953	30.21	19.0	218.30	11.18
814-79	581	1190	48.82	32.1	214.97	18.06
817-78	294	1078	27.27	25.7	108.78	10.09
826-79	586	2475	23.68	26.5	216.82	8.76
862-80	458	2534	18.07	15.3	169.46	6.69
867-82	321	3243	9.90	11.9	118.77	3.66
873-80	564	6298	8.96	20.1	208.68	3.31
876-79	393	406	96.80	39.7	145.41	35.82
880-79	2691	2366	113.74	73.3	995.67	42.08
885-80	704	2595	27.13	20.4	260.48	10.04
887-77	576	1565	36.81	42.1	213.12	13.62
892-77	278	810	34.32	59.6	102.86	12.70
896-78	395	780	50.64	69.7	146.15	18.74
898-80	503	1662	30.26	37.6	186.11	11.20
TOTAL	18252	81594			6753.24	

SAMPLE CALCULATIONS FOR TABLES 7-3-1 TO 7-3-3

The third column titled 'NG Yearly S.C.F. (Standard Cubic Feet)' is the mass of natural gas consumed converted into a volume at standard conditions (14.7 psia, 70°F) and is calculated as follows:

L.S.C. NG kg = 3802.232kg TABLE 7-3-3

$$\text{NG Yearly S.C.F.} = 3802.232 \times 50 \ \frac{\text{S.C.F.}}{\text{kg}}$$

$$= 190112 \text{ S.C.F.}$$

The column titled 'NG S.C.F./Gal' is the volume of natural gas at standard conditions that contains the same number of btu's as a gallon of gasoline and is calculated as follows:

NG Yearly S.C.F. = 190112 S.C.F. TABLE 7-3-3
Equiv L Gasoline = 6133 Litres TABLE 7-3-3

$$\text{NG } \frac{\text{S.C.F.}}{\text{Gal}} = \frac{190112 \text{ S.C.F.}}{6133\text{L}} \times 4.5461 \text{ L/Gal.}$$

$$= 140.921 \ \frac{\text{S.C.F.}}{\text{Gal}}$$

The cost to operate on NG and the cost per kilometre are calculated the same way as explained in the sample calculations to TABLES 7-2-1 to 7-2-3.

UNION GAS LTD. 2 YEAR N.G. OPERATING DATA SUMMARY

VEHICLE NUMBER	NATURAL GAS KILOGRAMS	NATURAL GAS KILOMETERS	2 YEAR TOTAL S.C.F.	N.G. EQUIV L. GASOLINE	AVERAGE N.G. SCF/GAL	N.G. COST TO OPERATE	OPERATI COST N. CENTS/K
375-78	703.799	8335	35190	1875.375	85.304	253.37	2.
380-82	2602.420	43011	130121	4043.034	146.312	936.87	2.1
387-72	1224.141	16787	61207	1930.505	144.135	440.69	2.
510-80	10729.243	48513	536462	18386.427	132.642	3862.53	7.
540-83	2434.379	21664	121719	4116.160	134.433	876.38	4.
650-80	4137.566	16131	206878	7355.736	127.858	1489.52	9.
762-82	7175.811	56176	358791	11965.488	136.317	2583.29	4.
773-80	2541.476	17961	127074	4041.225	142.949	914.93	5.1
778-80	2346.431	11721	117322	2789.598	191.194	844.72	7.
779-80	1072.714	15553	53636	1990.784	122.481	386.18	2.
800-77	3525.641	24886	176282	6271.272	127.788	1269.23	5.1
801-83	2275.821	17264	113791	3280.160	157.707	819.30	4.
814-79	3028.806	18627	151440	5979.267	115.142	1090.37	5.
817-78	2480.654	17979	124033	4620.603	122.033	893.04	4.
826-79	2947.448	19237	147372	5097.805	131.423	1061.08	5.
862-80	2761.153	29940	138058	4580.820	137.011	994.02	3.
867-82	3097.697	47294	154885	5627.986	125.111	1115.17	2.
873-80	2202.290	18408	110115	3700.008	135.295	792.82	4.4
876-79	2635.107	8378	131755	3326.066	180.085	948.64	11.
880-79	7003.621	17461	350181	12798.913	124.382	2521.30	14.
885-80	2102.473	21116	105124	4307.664	110.942	756.89	3.
887-77	4824.006	19589	241200	8246.969	132.960	1736.64	8.
892-77	4071.850	12291	203593	7325.436	126.348	1465.87	11.
896-78	1371.815	2049	68591	1428.153	218.338	493.85	23.
898-80	1052.575	4089	52629	1537.464	155.617	378.93	10.
TAL	80348.937	534460	4017449	136622.918		28925.63	

TABLE 7-3-2

UNION GAS LTD. 2ND YEAR N.G. OPERATING DATA

VEHICLE NUMBER	NATURAL GAS KILOGRAMS	NATURAL GAS KILOMETERS	N.G. YEARLY S.C.F.	N.G. EQUIV L GASOLINE	N.G. SCF/GAL	OPERATE N.G. AT.36/KG	OPERATI COST N. CENTS/K .36/KG
375-78	7.856	1950	393	438.750	4.070	2.83	.
380-82	1091.752	20208	54588	1899.552	130.642	393.03	1.
387-72	499.832	6699	24992	770.385	147.477	179.94	2.
510-80	4443.180	21832	222159	8274.328	122.059	1599.54	7.
540-83	1059.820	9513	52991	1807.470	133.282	381.54	4.
650-80	2036.413	7958	101821	3628.848	127.558	733.11	9.
762-82	3373.579	27393	168679	5834.709	131.426	1214.49	4.
773-80	1327.112	9195	66356	2068.875	145.808	477.76	5.
778-80	1220.255	6465	61013	1538.670	180.266	439.29	6.
779-80	510.306	7476	25515	956.928	121.216	183.71	2.
800-77	1760.523	11782	88026	2969.064	134.782	633.79	5.
801-83	1170.977	8856	58549	1682.640	158.185	421.55	4.
814-79	1457.100	8826	72855	2833.146	116.904	524.56	5.
817-78	1141.129	8177	57056	2101.489	123.429	410.81	5.
826-79	1354.030	9678	67702	2564.670	120.007	487.45	5.
862-80	1284.676	13866	64234	2121.498	137.645	462.48	3.
867-82	1489.961	23337	74498	2777.103	121.953	536.39	2.
873-80	657.687	5118	32884	1028.718	145.322	236.77	4.
876-79	1021.578	3446	51079	1368.062	169.736	367.77	10.
880-79	2312.197	6670	115610	4889.110	107.499	832.39	12.
885-80	990.125	10093	49506	2058.972	109.307	356.45	3.
887-77	2272.786	9588	113639	4036.548	127.985	818.20	8.
892-77	1687.416	5539	84371	3301.244	116.186	607.47	10.
896-78	355.601	558	17780	388.926	207.828	128.02	22.
898-80	195.597	573	9780	215.448	206.362	70.41	12.
TAL	34721.488	244796	1736076	61555.153		12499.75	

TABLE 7-3-3

UNION GAS LTD. 1ST YEAR N.G. OPERATING DATA

VEHICLE NUMBER	1ST YEAR N.G. KILOGRAMS	1ST YEAR N.G. KILOMETERS	N.G. YEARLY S.C.F.	EQUIV L GASOLINE	N.G. SCF/GAL	OPERATE N.G. AT.36/KG	COST N.G CENTS/KM 36/KG
375-78	695.943	6385	34797	1437	110.084	250.54	3.9
380-82	1510.668	22803	75533	2143	160.234	543.84	2.3
387-82	724.309	10088	36215	1160	141.930	260.75	2.5
510-80	6286.063	26681	314303	10112	141.303	2262.98	8.4
540-83	1374.559	12151	68728	2309	135.316	494.84	4.0
650-80	2101.153	8173	105058	3727	128.147	756.42	9.2
762-82	3802.232	28783	190112	6131	140.967	1368.80	4.7
773-80	1214.364	8766	60718	1972	139.975	437.17	4.9
778-80	1126.176	5256	56309	1251	204.625	405.42	7.7
779-80	562.408	8077	28120	1034	123.635	202.47	2.5
800-77	1765.118	13104	88256	3302	121.508	635.44	4.8
801-83	1104.844	8408	55242	1598	157.157	397.74	4.7
814-79	1571.706	9801	78585	3146	113.559	565.81	5.7
817-78	1339.525	9802	66976	2519	120.874	482.23	4.9
826-79	1593.418	9559	79671	2533	142.989	573.63	6.0
862-80	1476.477	16074	73824	2459	136.483	531.53	3.3
867-82	1607.736	23957	80387	2851	128.182	578.78	2.4
873-80	1544.603	13290	77230	2671	131.447	556.06	4.1
876-79	1613.529	4932	80676	1958	187.315	580.87	11.7
880-79	4691.424	10791	234571	7910	134.815	1688.91	15.6
885-80	1112.348	11023	55617	2249	112.424	400.45	3.6
887-77	2551.220	10001	127561	4210	137.745	918.44	9.1
892-77	2384.434	6752	119222	4024	134.690	858.40	12.7
896-78	1016.214	1491	50811	1039	222.320	365.84	24.5
898-80	856.978	3516	42849	1322	147.349	308.51	8.7
TOTAL	45627.449	289664	2281371	75067		16425.87	

SAMPLE CALCULATIONS FOR TABLES 7-4-1 TO 7-4-3

The column titled 'NG/Gas Percentage Savings' is the percentage in terms of cost per kilometre saved by running on natural gas over gasoline.

¢/km NG = 4.76 TABLE 7-3-3
¢/km Gasoline = 13.53 TABLE 7-2-3

$$\frac{\text{NG}}{\text{Gas}} \text{ Percent Saving} = \frac{13.53 - 4.76}{13.53} \times 100\%$$

$$= 64.82\%$$

The two-year percentage savings is simply an average of the savings for the two years of the study.

TABLE 7-4-1

UNION GAS LTD. 2ND YEAR NG/GASOLINE AVERAGE SAVINGS

VEHICLE NUMBER	MAKE	TYPE	MODEL	NG/GAS PERCENT SAVINGS
375-78	DODGE	L.B. VAN	B-200	76.56
380-82	FORD	HATCH	ESCORT	55.70
387-82	GMC	4-DR SEDAN	CIERA	44.37
510-80	DODGE	DEL. VAN	D-300	45.37
540-83	FORD	1/4-T P.U.	RANGER	58.08
650-80	FORD	DEL. VAN	F-350	1.54
762-82	DODGE	4-WD P.U.	W-150	67.64
773-80	DODGE	S.B. VAN	B-200	51.54
778-80	FORD	S.B. VAN	E-150	13.66
779-80	PLYMOUTH	HATCH	HORIZON	15.15
800-77	DODGE	L.B. VAN	B-200	-5.31
801-83	FORD	1/4-T P.U.	RANGER	56.97
814-79	FORD	L.B. VAN	E-150	-7.08
817-78	DODGE	L.B. VAN	B-200	63.21
826-79	FORD	S.B. VAN	E-150	25.69
862-80	GMC	4-DR SEDAN	LAURENTIAN	43.21
867-82	FORD	5-DR WAGON	ESCORT	48.92
873-80	DODGE	S.B. VAN	B-200	-16.36
876-79	DODGE	WELDER	D-300	34.34
880-79	FORD	3-CU DUMP	LN-800	60.64
885-80	DODGE	S.B. VAN	B-200	39.08
887-77	DODGE	UTILITY	D-300	37.37
892-77	DODGE	UTILITY	D-300	-1.60
896-78	DODGE	UTILITY	D-300	-5.70
898-80	DODGE	UTILITY	D-300	9.60

TABLE 7-4-2

UNION GAS LTD. 2ND YEAR NG/GASOLINE SAVINGS REPORT

VEHICLE NUMBER	MAKE	TYPE	MODEL	NG/GAS PERCENT SAVINGS
375-78	DODGE	L.B. VAN	B-200	98.49
380-82	FORD	HATCH	ESCORT	74.61
387-82	GMC	4-DR SEDAN	CIERA	45.98
510-80	DODGE	DEL. VAN	D-300	67.65
540-83	FORD	1/4-T P.U.	RANGER	48.72
650-80	FORD	DEL. VAN	F-350	-11.10
762-82	DODGE	4-WD P.U.	W-150	70.45
773-80	DODGE	S.B. VAN	B-200	59.53
778-80	FORD	S.B. VAN	E-150	5.83
779-80	PLYMOUTH	HATCH	HORIZON	31.09
800-77	DODGE	L.B. VAN	B-200	-69.72
801-83	FORD	1/4-T P.U.	RANGER	56.25
814-79	FORD	L.B. VAN	E-150	-82.21
817-78	DODGE	L.B. VAN	B-200	75.17
826-79	FORD	S.B. VAN	E-150	19.87
862-80	GMC	4-DR SEDAN	LAURENTIAN	35.89
867-82	FORD	5-DR WAGON	ESCORT	63.95
873-80	DODGE	S.B. VAN	B-200	-6.44
876-79	DODGE	WELDER	D-300	1.57
880-79	FORD	3-CU DUMP	LN-800	58.46
885-80	DODGE	S.B. VAN	B-200	14.32
887-77	DODGE	UTILITY	D-300	41.50
892-77	DODGE	UTILITY	D-300	
896-78	DODGE	UTILITY	D-300	-62.81
898-80	DODGE	UTILITY	D-300	

TABLE 7-4-3

UNION GAS LTD. 1ST YEAR NG/GAS SAVINGS PERCENT

VEHICLE NUMBER	MAKE	TYPE	MODEL	NG/GAS PERCENT SAVINGS
375-78	DODGE	L.B. VAN	B-200	54.63
380-82	FORD	HATCH	ESCORT	36.19
387-82	GMC	4-DR SEDAN	CIERA	42.79
510-80	DODGE	DEL. VAN	D-300	23.12
540-83	FORD	1/4-T P.U.	RANGER	69.44
650-80	FORD	DEL. VAN	F-350	14.18
762-82	DODGE	4-WD P.U.	W-150	64.82
773-80	DODGE	S.B. VAN	B-200	43.55
778-80	FORD	S.B. VAN	E-150	21.49
779-80	PLYMOUTH	HATCH	HORIZON	-0.80
800-77	DODGE	L.B. VAN	B-200	59.11
801-83	FORD	1/4-T P.U.	RANGER	57.69
814-79	FORD	L.B. VAN	E-150	68.05
817-78	DODGE	L.B. VAN	B-200	51.24
826-79	FORD	S.B. VAN	E-150	31.51
862-80	GMC	4-DR SEDAN	LAURENTIAN	50.52
867-82	FORD	5-DR WAGON	ESCORT	33.88
873-80	DODGE	S.B. VAN	B-200	-26.28
876-79	DODGE	WELDER	D-300	67.11
880-79	FORD	3-CU DUMP	LN-800	62.81
885-80	DODGE	S.B. VAN	B-200	63.84
887-77	DODGE	UTILITY	D-300	32.60
892-77	DODGE	UTILITY	D-300	-0.08
896-78	DODGE	UTILITY	D-300	-30.95
898-80	DODGE	UTILITY	D-300	21.70

SAMPLE CALCULATIONS FOR TABLES 7-5-1 TO 7-5-3

The columns titled 'Gasoline btu/km' and 'NG btu/km' are an indication of the fuel energy consumed to travel a kilometre on gasoline and natural gas and are calculated as follows:

$$\text{B.C. L/100km} = (31062 \text{ btu/L}) \times \frac{21.3}{100}$$

$$= 6616.21 \text{ btu/km}$$

$$\text{kg/km NG} = \frac{3802.232}{28783}$$

$$= 0.132 \text{ kg/km}$$

$$\text{NG btu/km} = (45730 \text{ btu/kg}) \times .132$$

$$= 6040.93 \text{ btu/km}$$

The column titled 'NG Btu/Gas Btu' is a ratio of the number of btu's consumed per kilometre on natural gas and gasoline.

TABLE 7-5-3

Gasoline Btu/km = 6616.21
NG Btu/km = 6040.94

$$\frac{\text{NG Btu}}{\text{Gas Btu}} = \frac{6040.94}{6616.21}$$

$$= .91$$

TABLE 7-5-1

UNION GAS LTD. 2 YEAR NG VS GASOLINE IN Btu/km

VEHICLE NUMBER	ENG DISP.	TYPE	NO. CYL.	GASOLINE Btu/km	NG Btu/km	NG Btu / GAS Btu
375-78	3.70	L.B. VAN	6	6988.95	2584.90	0.37
380-82	1.60	HATCH	4	2919.83	2748.96	0.95
387-82	2.80	4-DR SEDAN	6	3572.13	3347.73	0.94
510-80	6.00	DEL. VAN	8	11772.50	10040.39	0.82
540-83	2.30	1/4-T P.U.	4	5901.78	5133.37	0.87
650-80	5.80	DEL. VAN	8	14164.27	11729.63	0.83
762-82	3.70	4-WD P.U.	6	6616.21	5836.40	0.88
773-80	3.70	S.B. VAN	6	6988.95	6466.63	0.93
778-80	4.90	S.B. VAN	6	7392.76	9215.69	1.25
779-80	1.70	HATCH	4	3975.94	3152.15	0.80
800-77	3.70	L.B. VAN	6	7827.62	6496.51	0.83
801-83	2.30	1/4-T P.U.	4	5901.78	6027.77	1.02
814-79	3.70	L.B. VAN	6	9970.90	7442.37	0.75
817-78	3.70	L.B. VAN	6	7982.93	6316.54	0.79
826-79	4.90	S.B. VAN	6	8231.43	7010.59	0.86
862-80	5.00	4-DR SEDAN	6	4752.49	4219.72	0.89
868-82	1.60	5-DR WAGON	4	3696.38	2994.07	0.81
873-80	3.70	S.B. VAN	6	6243.46	5595.18	0.90
876-79	6.00	WELDER	8	12331.61	14259.84	1.15
880-79	6.00	3-CU DUMP	8	22768.45	17867.99	0.78
885-80	3.70	S.B. VAN	6	6336.65	4550.14	0.72
887-77	5.20	UTILITY	8	13077.10	11252.89	0.86
892-77	5.20	UTILITY	8	18512.95	15039.29	0.81
896-78	5.20	UTILITY	8	21650.21	30156.17	1.90
898-80	6.00	UTILITY	8	11679.31	13377.30	1.15

TABLE 7-5-2

UNION GAS LTD. 2 YEAR NG VS GASOLINE IN Btu/km

VEHICLE NUMBER	ENG DISP.	TYPE	NO. CYL.	GASOLINE Btu/km	NG Btu/km	NG Btu / GAS Btu
375-78	3.70	L.B. VAN	6	6988.95	184.23	0.03
380-82	1.60	HATCH	4	2919.83	2470.59	0.85
387-82	2.80	4-DR SEDAN	6	3572.13	3412.05	0.96
510-80	6.00	DEL. VAN	8	11772.50	9306.80	0.79
540-83	2.30	1/4-T P.U.	4	5901.70	5094.67	0.86
650-80	5.80	DEL. VAN	8	14164.27	11702.00	0.83
762-82	3.70	4-WD P.U.	6	6616.21	5631.87	0.85
773-80	3.70	S.B. VAN	6	6988.95	6599.64	0.94
778-80	4.90	S.B. VAN	6	7392.76	8631.44	1.17
779-80	1.70	HATCH	4	3975.94	3121.47	0.79
800-77	3.70	L.B. VAN	6	7827.62	6833.19	0.87
801-83	2.30	1/4-T P.U.	4	5901.78	6046.61	1.02
814-79	3.70	L.B. VAN	6	9970.90	7549.50	0.76
817-78	3.70	L.B. VAN	6	7982.93	6381.78	0.79
826-79	4.90	S.B. VAN	6	8231.43	6397.99	0.78
862-80	5.00	4-DR SEDAN	6	4752.49	4236.80	0.89
868-82	1.60	5-DR WAGON	4	3696.38	2919.65	0.79
873-80	3.70	S.B. VAN	6	6243.46	5876.59	0.94
876-79	6.00	WELDER	8	12331.61	13556.80	1.09
880-79	6.00	3-CU DUMP	8	22768.45	15852.50	0.69
885-80	3.70	S.B. VAN	6	6336.65	4486.12	0.71
887-77	5.20	UTILITY	8	13077.10	10840.00	0.83
892-77	5.20	UTILITY	8	18512.95	13931.31	0.75
896-78	5.20	UTILITY	8	21650.21	29142.70	1.35
898-80	6.00	UTILITY	8	11679.31	15610.20	1.34

TABLE 7-5-3

UNION GAS LTD. 1ST YEAR NG VS GASOLINE IN Btu/km

VEHICLE NUMBER	ENG DISP.	NO. CYL.	GASOLINE Btu/km	NG Btu/km	NG Btu / GAS Btu	CONTROL GROUP Btu/km
375-78	3.70	6	6988.95	4984.57	0.71	7765.50
380-82	1.60	4	2919.83	3027.33	1.04	3727.44
387-82	2.80	6	3572.13	3283.41	0.92	3106.20
510-80	6.00	8	11772.50	10773.99	0.92	15220.38
540-83	2.30	4	5901.78	5172.06	0.88	5901.78
650-80	5.80	8	14164.27	11757.18	0.83	8076.12
762-82	3.70	6	6616.21	6040.93	0.91	6833.64
773-80	3.70	6	6988.95	6333.61	0.91	8076.12
778-80	4.90	6	7392.76	9799.94	1.33	9007.98
779-80	1.70	4	3975.94	3182.81	0.80	4659.30
800-77	3.70	6	7827.62	6195.83	0.79	8697.36
801-83	2.30	4	5901.78	6008.92	1.02	4969.92
814-79	3.70	6	9970.90	7335.09	0.74	13356.66
817-78	3.70	6	7982.93	6251.29	0.78	10250.46
826-79	4.90	6	8231.43	7623.19	0.93	11182.32
862-80	5.00	6	4752.49	4202.59	0.88	4038.06
867-82	1.60	4	3696.38	3068.48	0.83	2484.96
873-80	3.70	6	6243.46	5313.83	0.85	5591.16
876-79	6.00	8	12334.61	14962.86	1.21	13046.04
880-79	6.00	8	22768.45	19883.40	0.87	25160.22
885-80	3.70	6	6336.675	4614.16	0.73	5901.78
887-77	5.20	8	13077.10	11665.72	0.89	8015.96
892-77	5.20	8	18512.95	16147.26	0.87	27334.56
896-78	5.20	8	21650.21	31169.57	1.44	20190.30
898-80	6.00	8	11679.31	11144.40	0.95	11182.32

TABLE 7-6-1

UNION GAS LTD. 2 YEAR NG VS GASOLINE ECONOMY

VEHICLE NUMBER	ENG DISP.	TYPE	OPERATING COST GASOLINE /km	GASOLINE Btu/km	OPERATING COST NG /km	NG Btu/km
375-78	3.70	L.B. VAN	9.74	6988.95	2.04	2584.90
380-82	1.60	HATCH	6.04	2919.83	2.16	2748.96
387-82	2.00	4-DR SEDAN	4.71	3572.13	2.64	3347.73
510-80	6.00	DEL. VAN	16.84	11772.50	7.91	10040.39
540-83	2.30	1/4-T P.U.	9.92	5901.78	4.04	5133.37
650-80	5.80	DEL. VAN	10.40	14164.27	9.24	11729.63
762-82	3.70	4-WD P.U.	14.46	6616.21	4.60	5836.40
773-80	3.70	S.B. VAN	10.29	6988.95	5.10	6466.63
778-80	4.90	S.B. VAN	8.34	7392.76	7.25	9215.69
779-80	1.70	HATCH	2.88	3975.94	2.79	3152.15
800-77	3.70	L.B. VAN	7.42	7827.62	5.12	6496.51
801-83	2.30	1/4-T P.U.	11.03	5901.78	4.75	6027.77
814-79	3.70	L.B. VAN	10.08	9970.90	5.86	7442.37
817-78	3.70	L.B. VAN	13.99	7982.93	4.97	6316.54
826-79	4.90	S.B. VAN	7.83	8231.43	5.52	7010.59
862-80	5.00	4-DR SEDAN	6.14	4752.49	3.33	4219.72
867-82	1.60	5-DR WAGON	4.89	3696.38	2.36	2994.07
873-80	3.70	S.B. VAN	3.52	6243.46	4.41	5595.18
876-79	6.00	WELDER	22.26	12331.61	11.23	14259.84
880-79	6.00	3-CU DUMP	35.07	22768.45	14.07	17867.99
885-80	3.70	S.B. VAN	7.47	6336.65	3.58	4550.14
887-77	5.20	UTILITY	14.14	13077.10	8.86	11252.89
892-77	5.20	UTILITY	11.65	18512.95	11.84	15039.29
896-78	5.20	UTILITY	15.12	21650.21	23.74	30156.17
898-80	6.00	UTILITY	11.66	11679.31	10.53	13377.50
TOTAL			275.89		167.94	

TABLE 7-6-2

UNION GAS LTD. 2 YEAR NG VS GASOLINE ECONOMY

VEHICLE NUMBER	ENG DISP.	TYPE	OPERATING COST GASOLINE /km	GASOLINE Btu/km	OPERATING COST NG /km	NG Btu/km
375-78	3.70	L.B. VAN	9.91	6988.95	0.15	184.23
380-82	1.60	HATCH	7.64	2919.83	1.94	2470.59
387-82	2.80	4-DR SEDAN	4.98	3572.13	2.69	3412.05
510-80	6.00	DEL. VAN	22.66	11772.50	7.33	9306.80
540-83	2.30	1/4-T P.U.	7.82	5901.78	4.01	5094.67
650-80	5.80	DEL. VAN	8.29	14164.27	9.21	11702.08
762-82	3.70	4-WD P.U.	14.99	6616.21	4.43	5631.87
773-80	3.70	S.B. VAN	12.85	6988.95	5.20	6599.64
778-80	4.90	S.B. VAN	7.21	7392.76	6.79	8631.44
779-80	1.70	HATCH	3.57	3975.94	2.46	3121.47
800-77	3.70	L.B. VAN	3.17	7827.62	5.38	6833.19
801-83	2.30	1/4-T P.U.	10.88	5901.78	4.76	6046.61
814-79	3.70	L.B. VAN	3.26	9970.90	5.94	7549.50
817-78	3.70	L.B. VAN	20.22	7982.93	5.02	6381.78
826-79	4.90	S.B. VAN	6.29	8231.43	5.04	6397.99
862-80	5.00	4-DR SEDAN	5.21	4752.49	3.34	4236.80
867-82	1.60	5-DR WAGON	6.38	3696.38	2.30	2919.65
873-80	3.70	S.B. VAN	4.35	6243.46	4.63	5876.59
876-79	6.00	WELDER	10.84	12331.61	10.67	13556.80
880-79	6.00	3-CU DUMP	30.04	22768.45	12.48	15852.50
885-80	3.70	S.B. VAN	4.12	6336.65	3.53	4486.12
887-77	5.20	UTILITY	14.58	13077.10	8.53	10840.00
892-77	5.20	UTILITY	10.45	18512.95	10.97	13931.31
896-78	5.20	UTILITY	14.09	21650.21	22.94	29142.70
898-80	6.00	UTILITY	12.00	11679.31	12.29	15610.20
TOTAL			255.80		162.03	

TABLE 7-6-3

UNION GAS LTD. 1ST YEAR N.G. VS GASOLINE ECONOMY

VEHICLE NUMBER	OPERATING COST GAS CENTS/KM .37/L	GASOLINE BTU/KM	OPERATING COST N.G. CENTS/KM 36/KG	N.G. BTU/KM	OPERATING COST CONTROL CENTS/KM	CONTROL GROUP BTU/KM
375-78	8.64	6988.95	3.92	4984.57	9.67	7765.50
380-82	3.73	2919.83	2.38	3027.33	4.60	3727.44
387-82	4.51	3572.13	2.58	3283.41	4.70	3106.20
510-80	11.03	11772.50	8.48	10773.99	15.00	15220.38
540-83	13.32	5901.78	4.07	5172.06	8.00	5901.78
650-80	10.79	14164.27	9.26	11757.18	14.39	8076.12
762-82	13.53	6616.21	4.76	6040.93	7.98	6833.64
773-80	8.84	6988.95	4.99	6333.61	3.70	8076.12
778-80	9.82	7392.76	7.71	9799.94	11.22	9007.98
779-80	2.49	3975.94	2.51	3182.81	4.52	4659.30
800-77	11.86	7827.62	4.85	6159.83	11.21	8697.36
801-83	11.18	5901.78	4.73	6008.92	6.83	4969.92
814-79	18.06	9970.90	5.77	7335.09	13.31	13356.66
817-78	10.09	7982.93	4.92	6251.29	13.78	10250.46
826-79	8.76	8231.43	6.00	7623.19	15.34	11182.32
862-80	6.69	4752.49	3.31	4202.59	3.38	4038.06
867-82	3.66	3696.38	2.42	3068.48	3.16	2484.96
873-80	3.31	6243.46	4.18	5313.83	7.66	5591.16
876-79	35.82	12331.61	11.78	14962.86	12.57	13046.04
880-79	42.08	22768.45	15.65	19883.40	29.83	25160.22
885-80	10.04	6336.65	3.63	4614.16	9.35	5901.78
887-77	13.62	13077.10	9.18	11665.72	13.94	18015.96
892-77	12.70	18512.95	12.71	16147.26	26.39	27334.56
896-78	18.74	21650.21	24.54	31169.57	24.85	20190.30
898-80	11.20	11679.31	8.77	11144.40	15.97	11182.32
TOTAL	304.51		173.10		291.35	

APPENDIX 8

OIL ANALYSIS

TABLE 8-1-1

UNION GAS LTD. 2ND YEAR OIL CHANGE ODOMETERS

VEHICLE NUMBER	ORIGINAL ODOMETER READING	FIRST CHANGE ODOMETER	REASON FOR CHANGE	SECOND CHANGE ODOMETER	REASON FOR CHANGE	THIRD CHANGE ODOMETER	REASON FOR CHANGE
375-78	52158	53384		54522	4	59644	
380-82	43245	56639		65129			
387-82	59308	67707	5	76255		92024	
510-80	114480	128647		142426			
540-83	18337	24952		28377		30761	
650-80	35835	39345		43898		45658	
762-82	56980	72100		80120		94184	
773-80	41895	46752		50630		53231	
778-80	56139	59912		62784		65861	
779-80	34244	38268		42704			
800-77	94670	98169		105720			
801-83	10944	18095		22094		24880	
814-79	40690	45469		47545		50156	
817-78	55874	60141		65142			
826-79	62267	68033		73168			
862-80	82185	91723		98825			
867-82	32332	40111		65203			
873-80	101694	109432		112366			
876-79	36060	37686		40659			
880-79	24596	33215		39484			
885-80	93095	98128	1	102653	1	105575	
887-77	108496	113178		119023			
892-77	45704	48750		51992		53448	
896-78	26955	28223		29541			
898-80	42736	44888		45727		46536	

1) ANTIFREEZE CONTAMINATE
2) CONTAMINATED SAMPLE
3) IMPROPER SAMPLING PROCEDURE
4) BEARING WEAR RATES ABOVE NORMAL
5) HIGH SILICON CONTENT
6) OIL VISCOSITY CHANGE

UNION GAS LTD. 1ST YEAR N.G. OIL CHANGE ODOMETERS

VEHICLE NUMBER	ORIGINAL ODOMETER READING	FIRST CHANGE ODOMETER	REASON FOR CHANGE	SECOND CHANGE ODOMETER	REASON FOR CHANGE	THIRD CHANGE ODOMETER	REASON FOR CHANGE
375-78	43899	50601		52128			
380-82	16769	36204	4	43245	4		
387-82	28208	28495	1	49278	4	59308	
510-80	90798	114480	4				
540-83	9726	18337	4				
650-80	21131	35836	4				
762-82	35411	41441	2	56980	4		
773-80	29218	39232		41895	4		
778-80	51554	56139	4				
779-80	22180	34244					
800-77	76448	90141		94670	4		
801-83	5681	10944					
814-79	27703						
817-78	41619	53404	4	55874	4		
826-79	49742	62267					
862-80	70270	71344	1	82185	4		
867-82	2002	24571	4	32332	4		
873-80	87727	101694					
876-79	30337	32928	4	32928	4	36060	
880-79	12888	21276	4	24596	4		
885-80	80856	84114	1	93095	1		
887-77	97334	108496	4				
892-77	37076	45704	4				
896-78	24325	26955	4				
898-80	35493	40906		42736			

1) ANTIFREEZE CONTAMINATE
2) CONTAMINATED SAMPLE
3) IMPROPER SAMPLING PROCEDURE
4) BEARING WEAR RATES ABOVE NORMAL
5) HIGH SILICON CONTENT
6) OIL VISCOSITY CHANGE

UNION GAS LTD. 2ND YEAR OIL CHANGE DATES

VEHICLE NUMBER	ORIGINAL DATE OIL	FIRST CHANGE DATE	REASON FOR CHANGE	SECOND CHANGE DATE	REASON FOR CHANGE	THIRD CHANGE DATE	REAS FOR CHANG
375-78	84,02,23	84,05,23		84,08,20	4	85,02,15	
380-82	84,03,21	84,10,02		85,01,24			
387-82	84,01,04	84,05,11	5	84,08,09		85,02,26	
510-80	84,02,02	84,08,03		85,02,01			
540-83	84,01,27	84,07,27		84,11,22		85,02,01	
650-80	83,11,17	84,05,24		84,11,14		85,02,13	
762-82	83,11,25	84,05,28		84,08,22		85,02,12	
773-80	84,01,27	84,07,24		84,12,03		85,03,06	
778-80	83,11,23	84,05,23		84,11,14		85,02,21	
779-80	83,11,23	84,05,29		84,11,19			
800-77	84,03,01	84,06,08		84,11,30			
801-83	83,11,23	84,06,04		84,11,26		85,02,20	
814-79	83,11,24	84,05,23		84,08,16		84,11,20	
817-78	84,01,27	84,07,20		85,02,19			
826-79	83,12,01	84,06,06		84,11,28			
862-80	83,11,10	84,05,09		84,11,09			
867-82	84,03,01	84,06,07		85,03,29			
873-80	83,12,15	84,06,14		84,12,14			
876-79	83,11,23	84,05,30		84,12,03			
880-79	83,11,25	84,06,27		85,03,13			
885-80	84,03,09	84,07,03	1	84,11,13	1	85,03,06	
887-77	83,11,24	84,05,15		84,11,09			
892-77	83,11,24	84,05,31		84,11,14		85,02,13	
896-78	83,11,11	84,05,30		84,11,19			
898-80	83,11,24	84,06,03		84,11,19		85,02,19	

1) ANTIFREEZE CONTAMINATE
2) CONTAMINATED SAMPLE
3) IMPROPER SAMPLING PROCEDURE
4) BEARING WEAR RATES ABOVE NORMAL
5) HIGH SILICON CONTENT
6) OIL VISCOSITY CHANGE

TABLE 8-2-2

UNION GAS LTD. 1ST YEAR OIL CHANGE DATES

VEHICLE NUMBER	ORIGINAL DATE OIL	FIRST CHANGE DATE	REASON FOR CHANGE	SECOND CHANGE DATE	REASON FOR CHANGE	THIRD CHANGE DATE	REASON FOR CHANGE
375-78	83,01,18	83,11,23		84,02,23			
380-82	83,03,08	83,12,05	4	84,03,21	4		
387-82	83,03,14	83,04,18	1	83,10,27	4	84,01,04	
510-80	82,08,01	84,02,02	4				
540-83	83,02,02	84,01,27	4				
650-80	82,09,19	83,11,17	4				
762-82	83,03,24	83,06,10	2	83,11,25	4		
773-80	82,10,08	83,10,31		84,01,27	4		
778-80	83,01,03	83,11,23	4				
779-80	83,01,08	83,11,23					
800-77	82,10,09	83,11,11		84,03,01	4		
801-83	82,10,26	83,11,23					
814-79	82,08,26						
817-78	82,11,08	83,10,31	4	84,01,27	4		
826-79	82,10,20	83,12,01					
862-80	83,03,09	83,03,28	1	83,11,10	4		
867-82	82,10,26	83,11,28	4	84,03,01	4		
873-80	82,09,15	83,12,15					
876-79	82,10,17	83,05,31	4	83,11,11	4	83,11,23	
880-79	82,08,15	83,08,09	4	83,11,25	4		
885-80	83,03,25	83,06,10	1	84,03,09	1		
887-77	82,10,29	83,11,24	4				
892-77	82,12,02	83,11,24	4				
896-78	82,11,05	83,11,11	4				
898-80	82,10,15	83,08,08		83,11,24			

1) ANTIFREEZE CONTAMINATE
2) CONTAMINATED SAMPLE
3) IMPROPER SAMPLING PROCEDURE
4) BEARING WEAR RATES ABOVE NORMAL
5) HIGH SILICON CONTENT
6) OIL VISCOSITY CHANGE

TABLE 8-3-1

UNION GAS LTD. 2ND YEAR OIL CHANGE MILEAGES

VEHICLE NUMBER	TYPE	NATURAL GAS km	GASOLINE km	YEARLY TOTAL km	NO. OF CHANGE IN 1 YR.	MILEAGE SINCE LAST CHANGE
375-78	L.B. VAN	1950	7191	9141	5	696
380-82	HATCH	20208	5422	25630	1	3801
387-82	4-DR SEDAN	6699	21628	28327	5	1468
510-80	DEL. VAN	21832	5186	27018	2	3457
540-83	1/4-T P.U.	9513	2926	12439	3	1759
650-80	DEL. VAN	7958	567	8525	3	1158
762-82	4-WD P.U.	27393	4087	31480	3	3746
773-80	S.B. VAN	9195	974	10169	3	895
778-80	S.B. VAN	6465	1578	8043	3	1024
779-80	HATCH	7476	1658	9134	2	3265
800-77	L.B. VAN	11782	1124	12906	2	3374
801-83	1/4-T P.U.	8856	1403	10259	3	963
814-79	L.B. VAN	8826	1393	10219	3	4412
817-78	L.B. VAN	8177	675	8852	2	881
826-79	S.B. VAN	9678	1501	11179	2	5159
862-80	4-DR SEDAN	13866	1484	15350	2	6614
868-82	5-DR WAGON	23337	2690	26027	2	
873-80	S.B. VAN	5118	1684	6802	2	3760
876-79	WELDER	3446	482	3928	2	1363
880-79	3-CU DUMP	6670	3300	9970	3	73
885-80	S.B. VAN	10093	1985	12078	3	3895
887-77	UTILITY	9588	1894	11482	2	4779
892-77	UTILITY	5539	713	6252	3	854
896-78	UTILITY	558	2734	3292	2	1419
898-80	UTILITY	573	2274	2847	3	1164

UNION GAS LTD. 1ST YEAR OIL CHANGE MILEAGES

VEHICLE NUMBER	MAKE	LIFE SINCE CONVERSION N.G.(KM)	LIFE SINCE CONVERSION GAS (KM)	YEARLY TOTAL KILOMETERS	NO.OF CHANGES IN 1 YR.	MILEAGE SINCE LAST CHANGE
375-78	DODGE	6385	1066	7451	2	561
380-82	FORD	22803	3721	26524	2	353
387-82	GMC	10088	28576	38664	2	4721
510-80	DODGE	26681	5146	31827	1	4385
540-83	FORD	12151	1808	13959	1	2744
650-80	FORD	8173	3113	11286	1	2479
762-82	DODGE	28783	2325	31108	1	9370
773-80	DODGE	8766	1707	10473	2	1615
778-80	FORD	5256	1206	6462	1	2812
779-80	PLYMOUTH	8077	2892	10969	1	2591
800-77	DODGE	13104	1079	14183	2	1119
801-83	FORD	8408	1953	10361		4640
814-79	FORD	9801	1190	10991	2	17078
817-78	DODGE	9802	1078	10880	1	1297
826-79	FORD	9559	2475	12034		3579
862-80	GMC	16074	2534	18608	2	7801
867-82	FORD	23957	3243	27200	1	1796
873-80	DODGE	13290	6298	19588	1	5173
876-79	DODGE	4932	406	5338	3	1152
880-79	FORD	10791	2366	13157	2	4991
885-80	DODGE	11023	2595	13618	1	1373
887-77	DODGE	10001	1565	11566	1	3824
892-77	DODGE	6752	810	7562	1	2092
896-78	DODGE	1491	780	2271	1	394
898-80	DODGE	3516	1662	5178	2	1024

VEHICLE DESCRIPTION

TABLE 9-1

UNION GAS LTD. VEHICLE DESCRIPTIONS

CODES	VEHICLE NUMBER	MAKE	TYPE	MODEL	USAGE	GROSS VEHICLE WEIGHT	ENG DISP.
1	375-70	DODGE	L.B. VAN	B-200	STORES	2767	3.70
2	380-82	FORD	HATCH	ESCORT	LOCATE		1.60
	387-82	GMC	4-DR SEDAN	CIERA	R. PARKER		2.80
	510-80	DODGE	DEL. VAN	D-300	C/S	4445	6.00
	540-83	FORD	1/4-T P.U.	RANGER	C/S	1905	2.30
4	650-80	FORD	DEL. VAN	F-350	GAS MEAS.	4354	5.80
3	762-82	DODGE	4-WD P.U.	W-150	PLANT MAIN	2721	3.70
6	773-80	DODGE	S.B. VAN	B-200	C/S	2767	3.70
	778-80	FORD	S.B. VAN	E-150	C/S	2767	4.90
3	779-80	PLYMOUTH	HATCH	HORIZON	LEAK SURV.		1.70
3	800-77	DODGE	L.B. VAN	B-200	C/S	2767	3.70
	801-83	FORD	1/4-T P.U.	RANGER	C/S	1905	2.30
	814-79	FORD	L.B. VAN	E-150	C/S	2767	3.70
	817-78	DODGE	L.B. VAN	B-200	C/S	2767	3.70
	826-79	FORD	S.B. VAN	E-150	C/S	2767	4.90
3	862-80	GMC	4-DR SEDAN	LAURENTIAN	GAS MEAS.		5.00
6	867-82	FORD	5-DR WAGON	ESCORT	LOCATE		1.60
6	873-80	DODGE	S.B. VAN	B-200	C/S	2767	3.70
5	876-79	DODGE	WELDER	D-300	D/M	4563	6.00
	880-79	FORD	3-CU DUMP	LN-800	D/M	14062	6.00
6	885-80	DODGE	S.B. VAN	B-200	C/S	2767	3.70
5	887-77	DODGE	UTILITY	D-300	D/M	4563	5.20
5	892-77	DODGE	UTILITY	D-300	D/M	4563	5.20
4	896-78	DODGE	UTILITY	D-300	D/M	4563	5.20
456	898-80	DODGE	UTILITY	D-300	D/M	4563	6.00

CODES

(1) CARRIES MORE WEIGHT AND TRAVELS MORE CITY KILOMETRES.
(2) TRAVELS MORE CITY KILOMETRES.
(3) JOB FUNCTION CHANGE ONLY.
(4) IDLE 1 MONTH OR MORE.
(5) AUXILARY MOUNTED EQUIPMENT.
(6) CARRIES MORE WEIGHT L/100 km GAS BEFORE CONVERSION WILL VARY.

TABLE 9-2

UNION GAS LTD. INSTALLED EQUIPMENT

VEHICLE	MAKE	REGULATOR MAKE	MIXER MAKE & TYPE	NO. CYL.	*STORAGE VOLUME OF NG LITRES	ENG. DISP.
375-78	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	120	3.70
380-82	FORD	RENZOLANDI (M)	CNG FIXED GAP	4	60	1.60
387-82	GMC	RENZOLANDI (M)	CNG VENTURI	6	60	2.80
510-80	DODGE	RENZOLANDI (SS)	CNG FIXED GAP	8	240	6.00
540-83	FORD	RENZOLANDI (M)	CNG FIXED GAP	4	60	2.30
650-80	FORD	RENZOLANDI (SS)	CNG FIXED GAP	8	240	5.80
762-82	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	180	3.70
773-80	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	120	3.70
778-80	FORD	RENZOLANDI (SM)	CNG VENTURI	6	120	4.90
779-80	PLYMOUTH	RENZOLANDI (M)	CNG VENTURI	4	60	3.70
800-77	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	120	3.70
801-83	FORD	RENZOLANDI (M)	CNG FIXED GAP	4	60	2.30
814-79	FORD	RENZOLANDI (SM)	CNG VENTURI	6	120	1.70
817-78	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	120	3.70
826-79	FORD	RENZOLANDI (SM)	CNG VENTURI	6	120	4.90
862-80	GMC	RENZOLANDI (SM)	CNG FIXED GAP	6	60	5.00
867-82	FORD	RENZOLANDI (M)	CNG FIXED GAP	4	60	1.60
873-80	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	120	3.70
876-79	DODGE	RENZOLANDI (SS)	ALTERNATE FUELS	8	240	6.00
880-79	FORD	RENZOLANDI (SS)	CNG GARRETSON	8	240	6.00
885-80	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	6	120	3.70
887-77	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	8	180	5.20
892-77	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	8	180	5.20
896-78	DODGE	RENZOLANDI (SS)	CNG FIXED GAP	8	180	5.20
898-80	DODGE	RENZOLANDI (SM)	CNG FIXED GAP	8	240	6.00

* STORAGE VOLUME IN LITRES / 60 EQUALS ON-BOARD NO. OF NG CYLINDERS

SAMPLE CALCULATIONS FOR TABLE 9-3

The last column of this Table is the loss in horsepower expressed as a percent when the engine is operated on natural gas instead of gasoline.

Horsepower on Gasoline = 70 H.P.)
) TABLE 9-3
Horsepower on Natural Gas = 65 H.P.)

$$\text{Horsepower Loss} = \frac{70 - 65}{70} \times 100\%$$

$$= 7\%$$

TABLE 9-3

UNION GAS LTD. ENGINE PERFORMANCE

VEHICLE NUMBER	MAKE	NO. CYL.	HORSEPOWER ON GASOLINE	HORSEPOWER ON NG	HORSEPOWER LOSS (PERCENT)
375-78	DODGE	6	70	65	7
380-82	FORD	4	45	35	22
387-82	GMC	6	60	55	8
510-80	DODGE	8	98	85	13
540-83	FORD	4	45	40	13
650-80	FORD	8	92	72	22
762-82	DODGE	6	70	65	7
773-80	DODGE	6	72	66	8
778-80	FORD	4	80	70	13
779-80	PLYMOUTH	6	44	43	2
800-77	DODGE	4	70	65	7
801-83	FORD	6	45	40	13
814-79	FORD	6	75	60	20
817-78	DODGE	6	70	64	9
826-79	FORD	6	80	70	13
862-80	GMC	4	70	62	11
867-82	FORD	6	45	35	22
873-80	DODGE	8	178	68	13
876-79	DODGE	8	20	95	21
880-79	FORD	6			
885-80	DODGE	8	172	65	10
887-77	DODGE	8	100	90	10
892-77	DODGE	8	00	90	10
896-78	DODGE	8	192	80	13
898-80	DODGE	8	100	90	10

TABLE 9-4

UNION GAS LTD. CONTROL GROUP

VEHICLE NUMBER	MODEL	CONTROL GROUP DESCRIPTION	BEFORE CONVERSION L/ 100 km GASOLINE	CONTROL GROUP L/100 km
375-78	B-200	B-200	22.5	25
380-82	ESCORT	ESCORT	9.4	12
387-82	CIERA	CIERA	11.5	10
510-80	D-300	D-300	37.9	49
540-83	RANGER	1/4-T P.U.	19.0	19
650-80	F-350	E-350	45.6	26
762-82	W-150	W-150	21.3	22
773-80	B-200	B-200	22.5	26
778-80	E-150	E-160	23.8	29
779-80	HORIZON	HORIZON	12.8	15
800-77	B-200	B-200	25.2	28
801-83	RANGER	1/4-T P.U.	19.0	16
814-79	E-150	E-150	32.1	43
817-78	B-200	B-200	25.7	33
826-79	E-150	E-150	26.5	36
862-80	LAURENTIAN	LAURENTIAN	15.3	13
867-82	ESCORT	ESCORT	11.9	8
873-80	B-200	B-200	20.1	18
876-79	D-300	D-300	39.7	42
880-79	LN-800	LN-800	73.3	81
885-80	B-200	B-200	20.4	19
887-77	D-300	D-300	42.1	58
892-77	D-300	D-300	59.6	88
896-78	D-300	D-300	69.7	65
898-80	D-300	D-300	37.6	36

APPENDIX 10

COMPUTER PROGRAMS

COMPUTER PROGRAMS

Equation 1 is the formula used in the 'MASS' program to calculate the volume of NG in the fuel tank.

$$Vs = \frac{PVTs\ Fpv^2}{PsT\ Fpvs^2} \qquad (1)$$

where:

Vs = volume of NG in fuel tank (ft^3)
V = reference volume of tank (ft^3)
(water capacity)
Ps = pressure of NG in fuel tank (psia)
P = reference pressure (psia)
Ts = temperature of NG in fuel tank (°R)
T = reference temperature (°R)
Fpv^3 = supercompressibility of NG in fuel tank
Fpv = supercompressibility of reference conditions

Note: 1. Reference conditions are STP.

2. $Fpv = \frac{1}{\sqrt{Z}}$ Z = compressibility factor

Equation 2 is the formula used in the 'SCFACT' subroutine to calculate the supercompressibility factor.

$$\mathrm{Fpv} = \frac{\left(\frac{B}{D} - D + \frac{n}{3\pi}\right)^{\frac{1}{2}}}{1 + \left(\frac{0.00132}{\tau^{3.25}}\right)} \qquad (2)$$

where:

Fpv = supercompressibility factor

$B = \frac{3 - mn^2}{9m\pi^2}$

$m = 0.0330978(\tau)^{-2} - 0.0221323(\tau)^{-3} + 0.0161353(\tau)^{-5}$

$n = \frac{0.2658271(\tau)^{-2} + 0.0457697(\tau)^{-4} - 0.133185(\tau)^{-1}}{m}$

$= \frac{\mathrm{Padj} + 14.7}{1000}$

$= \frac{\mathrm{Tadj} + 460}{500}$

$\mathrm{Padj} = P \times \mathrm{Fp}$

P = gauge pressure (psig)

$\mathrm{Fp} = \frac{156.47}{160.8 - 722G + \mathrm{Kp}}$

$\mathrm{Kp} = \mathrm{Mc} - 0.392\ \mathrm{Mn}$

G = specific gravity of gas

Mc = mole percent carbon dioxide

Mn = mole percent nitrogen

$\mathrm{Tadj} = [(T + 460)F] - 460$

T = natural gas temperature (°F)

$F = \frac{226.29}{9.15 + 211.9\ G - K}$

$K = \mathrm{Mc} + 1.681\ \mathrm{Mn}$

$D = \left(b + (b^2 + B^3)^{1/2}\right)^{1/3}$

$b = \frac{9n - 2mn^3}{54m\pi^3} - \frac{E}{2m\pi^2}$

E = supercompressibility parameter

$$E_1 = 1 - 0.00075(\pi)^{2.3} e^{-20(\tau-1.09)} - \ldots$$

$$- 0.0011 (\tau - 1.09)^{0.5}$$

$$(\pi)^2 [2.17 + 1.4 (\tau - 1.09)^{0.5} - \pi]^2$$

PRESSURE RANGE:
π, 0 to 2, or p, 0 to 2000 psia

TEMPERATURE RANGE:
τ, 1.09 to 1.4, or t, 85°F to 240°F

$$E_2 = 1 - 0.00075(\pi)^{2.3} [2 - e^{-20(1.09-\tau)}] - \ldots$$

$$- 1.317(1.09 - \tau)^4 (\pi) \quad (1.69 - \pi^2)$$

PRESSURE RANGE:
π, 0 to 1.3, or p, 0 to 1300 psia

TEMPERATURE RANGE:
τ, 0.84 to 1.09, or t, − 40°F to 85°F

$$E_3 = 1 - 0.00075(\pi)^{2.3} [2 - e^{-20(1.09-\tau)}] + \ldots$$

$$+ 0.455 [200(1.09 - \tau)^6 - \ldots$$
$$- 0.03249 (1.09 - \tau) + \ldots$$
$$+ 2.0167(1.09 - \tau)^2 - \ldots$$

$$- 18.028(1.09 - \tau)^3 + 42.844(1.09 - \tau)^4]$$

$$(\pi - 1.3) \; [1.69(2)^{1.25} - \pi^2]$$

PRESSURE RANGE:
π, 1.3 to 2.0, or p, 1300 to 2000 psia

TEMPERATURE RANGE:
τ, 0.88 to 1.09, or t, — 20°F to 85°F

$$E \; = E_3 - Y$$

PRESSURE RANGE:
π, 2.0 to 5.0, or p, 2000 to 5000 psia

TEMPERATURE RANGE:
τ, 0.88 to 1.09, or t, − 20°F to 85°F

$$E_5 = E_1 - Y$$

PRESSURE RANGE:
π, 2.0 to 5.0, or p, 2000 to 5000 psia

TEMPERATURE RANGE:
τ, 1.09 to 1.32, or t, 85°F to 200°F

$$Y = A(\pi - 2) + A_1(\pi - 2)^2 + A_2(\pi - 2)^3 + \ldots + A_3(\pi - 2)^4$$

where:

$$A = 1.71720 - 2.33123(\tau) - 1.56796(\tau)^2 + \ldots + 3.47644(\tau)^3 - 1.28603(\tau)^4$$

$$A_1 = 0.016299 - 0.028094(\tau) + 0.48782(\tau)^2 - \ldots - 0.728221(\tau)^3 + 0.27839(\tau)^4$$

$$A_2 = -0.35978 + 0.51419(\tau) + 0.16453(\tau)^2 - \ldots - 0.52216(\tau)^3 + 0.19687(\tau)^4$$

$$A_3 = 0.075255 - 0.10573(\tau) - 0.058598(\tau)^2 + \ldots + 0.14416(\tau)^3 - 0.054533(\tau)^4$$

where:

$$U = (\tau - 1.32)^2(\pi - 2)\,[3 - 1.483(\pi - 2) - \ldots - 0.10(\pi - 2)^2 + 0.0833(\pi - 2)^3]$$

NOTE: In equations E4 and E5, if the value of is in excess of 2.0, then use 2.0

PROGRAM 'MASS'

```
[  0] MASS;PS;TS;P1;P2;T1;T2;VT;P;TEMP;Z;PCV;VA;VB;VOL;V1;V
[  1] ⍝ PROGRAM CALCULATES VOLUME OF NATURAL GAS STORED IN FUEL TANK(S) USING
[  2] ⍝ PRESSURE/TEMPERATURE RELATIONSHIP AND COMPARES THIS VALUE TO THE
[  3] ⍝ MEASURED AMOUNT
[  4] ⍝ INPUT WATER CAPACITY OF FUEL TANKS
[  5] ⍝ 'FUEL TANK WATER CAPACITY IN LITRES'
[  6] VT←180
[  7] V←VT×0.035315
[  8] ⍝ INPUT TEMP AND PRESS BEFORE AND AFTER FILL
[  9] 'TEMP (DEG C) AND PRESS (PSIG) AT START OF FILL'
[ 10] TS←⎕
[ 11] PS←⎕
[ 12] P1←PS+14.7
[ 13] 'TEMP (DEG C) AND PRESS (PSIG) AT FINISH OF FILL'
[ 14] TF←⎕
[ 15] PF←⎕
[ 16] P2←PF+14.7
[ 17] P←PS
[ 18] PC←P1
[ 19] TEMP←32+((9÷5)×TS)
[ 20] ⍝ CALCULATE SUPERCOMPRESSIBILITY FACTOR
[ 21] AA:Z←SCFACT
[ 22] ⍝ CALCULATE VOLUME IN TANK(S)
[ 23] VA←PC×V×520×Z*2
[ 24] VB←(TEMP+460)×14.7×0.9999893783*2
[ 25] VOL←VA÷VB
[ 26] →(P=PF)/AB
[ 27] PC←P2
[ 28] V1←VOL
[ 29] TEMP←32+((9÷5)×TF)
[ 30] P←PF
[ 31] →AA
[ 32] ⍝ CALCULATE VOLUME PUT INTO FUEL TANK(S) (SCF)
[ 33] AB:VTOT←VOL-V1
[ 34] ⍝ CALCULATE MASS (KG)
[ 35] M←VTOT×0.020065921
[ 36] M
[ 37] 'MEASURED AMT. (KG)'
[ 38] KG←⎕
[ 39] D←100×(KG-M)÷M
[ 40] D
[ 41]
```

SUBROUTINE 'SCFACT'

```
[ 0] Z←SC;ACT;N2;C;G;PADJ;PI;TAU;M;N;B;U;V1;V1A;V2;V2A;W;A;A1;A2;A3;Y;E2;E3;E1;SB;B1;B2;D;[illegible]
[ 1] ⍝'THIS PROGRAM CALCULATES THE SUPERCOMPRESSIBILITY FACTOR FOR NATURAL'
[ 2] ⍝'GAS FOR THE TEMPERATURE RANGE OF -20oF TO 200oF AND THE PRESSURE RANGE'
[ 3] ⍝'OF 0 PSIG TO 5000 PSIG. THIS PROGRAM USES FISCAL 1982 COMPANY FIGURES'
[ 4] ⍝'FOR MOLE PERCENT OF NITROGEN AND CARBON DIOXIDE, AND THE SPECIFIC'
[ 5] ⍝'GRAVITY OF THE NATURAL GAS'
[ 6] ⍝'MOLE PERCENT OF CO2 = 0.369'
[ 7] ⍝'MOLE PERCENT OF N2  = 1.922'
[ 8] ⍝'SPECIFIC GRAVITY    = 0.578'
[ 9] ⍝' '
[ 10] ⍝'ENTER PRESSURE (PSIG)'
[ 11] ⍝P←⎕
[ 12] ⍝'ENTER TEMPERATURE (DEG F)'
[ 13] ⍝TEMP←⎕
[ 14] N2←1.922
[ 15] C←0.369
[ 16] G←0.578
[ 17] ⍝ CALCULATION OF THE ADJUSTED PRESSURE FOUND BY MULTIPLYING THE
[ 18] ⍝ GAGE PRESSURE OF THE FLOWING GAS BY THE PRESSURE ADJUSTING FACTOR
[ 19] PADJ←P×(156.47÷(160.8+(C-0.392×N2)-7.22×G))
[ 20] ⍝ CALCULATION OF THE CONSTANT 'PI'
[ 21] PI←(14.7+PADJ)÷1000
[ 22] ⍝ CALCULATION OF THE CONSTANT 'TAU' USING THE ADJUSTED TEMPERATURE
[ 23] TAU←((TEMP+460)×226.29÷(99.15+(211.9×G)-(C+1.681×N2)))÷500
[ 24] ⍝ CALCULATION OF THE CONSTANT 'M'
[ 25] M←(0.0161353×TAU*¯5)+(0.0330378×TAU*¯2)-0.0221323×TAU*¯3
[ 26] ⍝ CALCULATION OF THE CONSTANT 'N'
[ 27] N←(((0.265827×TAU*¯2)+(0.0457697×TAU*¯4))-0.133185×TAU*¯1)÷M
[ 28] ⍝ CALCULATION OF THE CONSTANT 'B'
[ 29] B←(3-M×N*2)÷9×M×PI*2
[ 30] ⍝ CONSTANTS USED IN CALCULATING THE PARAMETER 'E'
[ 31] U←1.09-TAU
[ 32] V1←0.00075×(PI*2.3)×(2-(*1)*(¯20×U))
[ 33] V1A←0.0036934×(2-(*1)*(¯20×U))
[ 34] V2←0.00075×(PI*2.3)×(*1)*(¯20×(TAU-1.09))
[ 35] V2A←0.0036934×(*1)*(¯20×(TAU-1.09))
[ 36] W←PI-2
[ 37] A←1.7172+(-2.33123×TAU)+(-1.56796×TAU*2)+(3.47644×TAU*3)-1.28603×TAU*4
[ 38] A1←0.016299+(-0.028094×TAU)+(0.48782×TAU*2)+(-0.728221×TAU*3)+(0.27839×TAU*4)
[ 39] A2←¯0.35978+(0.51419×TAU)+(0.16453×TAU*2)+(-0.52216×TAU*3)+(0.19687×TAU*4)
[ 40] A3←0.075255+(-0.10573×TAU)+(-0.058598×TAU*2)+(0.14416×TAU*3)+(-0.054533×TAU*4)
[ 41] Y←A×W+(A1×W*2)+(A2×W*3)+A3×W*4
[ 42] ⍝ FINDING THE CORRECT RANGE FOR THE CALCULATION OF THE PARAMETER 'E'
[ 43] ⍝ NOTE: IF PI>2 FOR THE RANGE OF 2000 PSIA TO 5000 PSIA, PI=2 WAS USED
[ 44] ⍝ IN ACCORDANCE WITH AGA FORMULA
[ 45] →(TEMP≥85)/EA
[ 46] →(TAU≥1.09)/EA
[ 47] →(TEMP<85)/ED
[ 48] →(TAU<1.09)/ED
[ 49] EA:→(P≥2000)/EB
[ 50] →(PI≥2)/EC
[ 51] ⍝ CALCULATION OF PARAMETER 'E' FOR TEMP>85 DEG F, PRESS<2000 PSIA, AND
[ 52] ⍝ PI<2
[ 53] E1←1-V2-0.0011×((TAU-1.09)*0.5)×(PI*2)×(2.17+(1.4×(TAU-1.09)*0.5)-PI)*2
[ 54] E←E1
[ 55] →CONT
[ 56] EB:→(PI≥2)/EC
[ 57] ⍝ CALCULATION OF THE PARAMETER 'E' FOR TEMP>85 DEG F, PRESS>2000 PSIA,
[ 58] ⍝ AND PI<2
[ 59]  E3←1-V1+0.455×((200×U*6)+(¯0.03249×U)+(2.0167×U*2)+(-18.028×U*3)+(42.844×U*4)×(PI-1.3)×(1.69×2*1.25)-PI*2
[ 60] E←E3-Y
[ 61] →CONT
[ 62] ⍝ CALCULATION OF THE PARAMETER 'E' FOR TEMP>85 DEG F, PRESS>2000 PSIA
[ 63] ⍝ AND PI≥2
[ 64] EC:E3A←1-V1A+0.455×((200×U*6)+(¯0.03249×U)+(2.0167×U*2)+(-18.028×U*3)+(42.844×U*4))×0.01366
[ 65] E←E3A-Y
[ 66] →CONT
[ 67] ED:→(P≥2000)/EE
[ 68] →(PI≥2)/EF
[ 69] →(P<2000)/EG
[ 70] →(PI<2)/EG
[ 71] ⍝ CALCULATION OF THE PARAMETER 'E' FOR TEMP<85 DEG F, PRESS>2000 PSIA
[ 72] ⍝ AND PI<2
[ 73] EE:→(PI≥2)/EF
[ 74] E1←1-V2-0.0011×((TAU-1.09)*0.5)×(PI*2)×(2.17+(1.4×(TAU-1.09)*0.5)-PI)*2
[ 75] E←E1-Y
[ 76] →CONT
[ 77] EF:→(TAU<1.09)/EC
[ 78] E1A←1-V2A-0.0011×((TAU-1.09)*0.5)×4×(2.17+(1.4×(TAU-1.09)*0.5)-2)*2
[ 79] E←E1A-Y
[ 80] →CONT
[ 81] EG:→(P≥1300)/EH
[ 82] ⍝ CALCULATION OF THE PARAMETER 'E' FOR TEMP<85 DEG F, AND
[ 83] ⍝ PRESS<1300 PSIA
[ 84] →(PI≥1.3)/EH
[ 85] E2←1-V1-1.317×(U*4)×PI×1.69-PI*2
[ 86] E←E2
[ 87] →CONT
[ 88] ⍝ CALCULATION OF THE PARAMETER 'E' FOR TEMP<85 DEG F, AND
[ 89] ⍝ 1300≤ PRESS ≤2000 PSIA
[ 90] EH:E3←1-V1+0.455×((200×U*6)+(-0.03249×U)+(2.0167×U*2)+(-18.028×U*3)+42.844×U*4)×(PI-1.3)×(1.69×2*1.25)-PI*2
[ 91] E←E3
[ 92] ⍝ CALCULATION OF THE CONSTANT 'SB'
[ 93] CONT:B1←((9×N)-2×M×M*3)÷54×M×PI*3
[ 94] B2←E÷(2×M×PI*2)
[ 95] SB←B1-B2
[ 96] ⍝ CALCULATION OF THE CONSTANT 'D'
[ 97] D←(SB+((SB*2)+B*3)*0.5)*(1÷3)
[ 98] ⍝'CALCULATION OF THE SUPERCOMPRESSIBILITY FACTOR'
[ 99] SF1←((¯1×D)+(3÷D)+(N÷(3×PI)))*(0.5)
[100] SF2←1+0.00132÷TAU*(3.25)
[101] Z←SCF←SF1÷SF2
[102] ⍞'FOR THE FOLLOWING CONDITIONS THE SUPERCOMPRESSIBILITY FACTOR OF'
[103] ⍞'NATURAL GAS HAS BEEN FOUND.'
[104] ⍞'TEMPERATURE (DEG F) ',⍕TEMP
[105] ⍞'PRESSURE (PSIG)     ',⍕P
[106] ⍞'SC FACTOR           ',⍕SCF
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REFERENCES

1. Sonntag, Richard E.; Van Wylen, Gordon J.
   Fundamentals of Classical Thermodynamics.
   New York: John Wiley & Sons, 1978.

2. American Gas Association. A.G.A. Manual for the Determination of Supercompressibility Factors for Natural Gas', December 1962.

ONTARIO UTILITIES SPECIFICATIONS

ONTARIO UTILITIES SPECIFICATION

FOR NATURAL GAS/GASOLINE VEHICLE CONVERSIONS

NUMBER NGV-001-1985-07-03

1.0 INTRODUCTION

1.1 This specification is an installation guide to which all approved and authorized natural gas vehicle (NGV) conversion shops must adhere, when converting gas Utility owned or operated vehicles to run on the dual fuelled system of compressed natural gas and gasoline.

1.2 All installations will be conducted in accordance with Amendment #1 of CAN1.B149.1-1980 "Installation of Compressed Natural Gas Fuel Systems and Containers on Highway Vehicles and Requirements for Refuelling Stations", latest edition. These governing Codes are the minimum requirements. Code interpretations will be resolved by the Utility.

1.3 The equipment installation must be conducted under the guidance of a fully qualified Class 'A' mechanic who holds a valid NGV equipment certificate issued by the Ontario Ministry of Consumer and Commercial Relations (MCCR).

1.4 The overall quality of the conversion, must be conducted in a workmanship manner, meet the Utilities level of safety, and be as close to O.E.M. quality as possible.

1.5 Prior to converting the vehicle, the general condition of the mechanical and electrical systems are to be verified. Any problems or deficiencies must be reported to the Utility prior authorization to the conversion.

1.6 The Utilities will have the right to conduct quality control inspections on all installations, at the conversion centre premises. Deficiencies will be rectified by the conversion centre at no cost to the Utilities.

2.0 NATURAL GAS FUEL CONTAINING CYLINDERS, FITTINGS, TUBING AND HARDWARE

2.1 Cylinders

2.1.1 No cylinder with a test date more than six months from date of manufacture will be installed. Cylinders with test dates more than six months old will be unacceptable.

2.1.2 All vehicle fuel cylinders which contain compressed natural gas must be either steel, steel composite or aluminum composite material, manufactured to CTC/DOT 3AA specifications and supplied by either Faber or CNG Cylinder Corporation, or a Utility approved equivalent.

2.1.3 Rubber packing material will be installed between the cylinder and the retaining bands of the mounting bracket system.

2.1.4 The cylinder retaining bands of the mounting bracket system will be of unitary construction, containing no welding.

2.1.5 Only CNG Fuel Systems, CNG Cylinder Corporation or Utility approved brackets will be allowed.

2.1.6 Utility approved load spreading back up plates of sufficient strength will be installed.

2.1.7 Exposed steel cylinders will be painted, prior to installation.

2.1.8 In automobiles, the fuel cylinders will be mounted in the trunk as far forward as to be directly over the rear axle, where practical.

2.1.9 In service vans and trucks, the location of the fuel cylinders will vary. Location, size, manufacturer and number of cylinders to be installed will be indicated by the Utility, to the conversion shop, in all cases.

2.1.10 Cylinders, if installed underneath the vehicle, will not be mounted within 250 mm of the exhaust system. Any deviation must be authorized by the Utility.

2.1.11 Trunk mounted cylinders in automobiles will be vented in accordance with the B149 Code, and burst discs must also be vented to the outside of the vehicle.

2.2 Fittings, Tubing and Hardware

2.2.1 A quarter turn 6000 psi Type 316 stainless steel emergency shut-off valve of any of Hoke manufacture, model numbers 7115G4Y, 7115H4Y, 7115G6Y or 7115F4Y, or a stainless steel emergency shut-off valve of Whitey manufacture, model numbers SS-83KF4, SS-83KS4 or SS-83KS6 must be installed in the main fuel supply line below the vehicle forward of the axle and within 300 mm of the rear wheel well, on automobiles. The track of the 1/4 turn valve will be weather protected or sheathed with a material which will protect it from corrosive road salt. The exact location must be marked clearly with Utility decals.

2.2.2 Master shut-off valves shall be readily accessible, from outside the vehicle.

2.2.3 All tubing must be either 1/4" O.D. x 0.035" minimum wall thickness or 3/8" O.D. x 0.049" minimum wall thickness seamless Type 316 stainless steel to ASTM A269/A213 specification. All tubing will be secured to the vehicle chassis with properly sized galvanized or stainless steel clamps, insulated to prevent metal to metal contact between the tubing and the clamp.

2.2.4 All tube fittings will be manufactured from Type 316 stainless steel, that is, body, nut and ferrules. Tube fittings will be either Swagelok or Gyrolok, but not a mixture of both on any single vehicle, with the exception of the 1/4 turn Hoke valve part numbers 7115G4Y, 7115G6Y and 7115H4Y.

2.2.5 All threaded fittings will be Type 316 stainless steel of either Hoke or Cajon manufacture.

2.2.6 All threads on threaded fittings will be coated with SWAK (Cajon) pipe thread sealant or a Utility approved equivalent. A curing time of 24 hours is recommended for the Swak material.

2.2.7 A 25 000 kPa minimum, nitrogen pressure test of 10 min duration will be conducted on the system downstream of the cylinder valve or the valve closest to the cylinder if a cylinder valve is not present. Thereafter, the system will be soap bubble leak tested, before depressurization and after the 10 minute pressure test.

3.0 REFUELLING POINT

3.1 The refuelling point on automobiles will be located at the rear of the vehicle, behind the rear licence plate, or under the hood. If this is impractical, the Utility will authorize the relocation.

3.2 The refuelling point in vans and trucks will be contained in a fuel box located on the side of the vehicle, or under the hood. Actual location or any deviation must be approved by the Utility.

3.3 The refuelling point will contain a NZIG fill block, a pressure gauge, with a corrosion resistant housing and an approved shut-off valve. Manual ventable dust plugs will be installed in all refuelling blocks.

3.4 An in-line check valve of either Nupro model numbers SS-4C-10, SS-6C-10 or Hoke model numbers 6233G4S, 6233G6S shall be installed on automobiles with tanks in the trunk and filler behind the rear licence plate or in the front grill.

3.5 In all cases, the location of the refuelling point is to be pre-approved by the Utility.

4.0 REGULATORS

4.1 All regulators will be three stage design complete with a primer circuit will be installed, until a utility approved alternative is available. The primer circuit must be manually controlled from the vehicle dashboard.

4.2 The regulator manufacturer, make and model will be Utility approved prior to the commencement of conversion. Presently approved regulators are the Tartarini RP 76, RP76S, RP76S+ and the Landi-Renzo TN1C, TN2C, TN2CS.

4.3 Regulators should be sized with a minimum OF 6% excess flow capacity for the designated vehicle, and should be selected in discussion with the utility, particularly with respect to engine sizes over 350 cubic inches.

4.4 Because the engine performance is affected by the temperature of the natural gas fuel, all presently approved regulators will be heated with engine coolant, through a thermostatically controlled operating temperature range of 100°F to 140°F. Other future configurations or systems will be considered by the utility, at that time.

4.5 The regulator will be mounted (1) as close to the firewall as practically possible, and (2) as close to the mixer as practically possible within the space limitations of the engine compartment, and in such a manner that the diaphragm of the regulator is parallel to the direction of travel of the vehicle.

4.6 The regulator's coolant line shall be connected in parallel to the vehicle's coolant lines.

5.0 MIXERS

5.1 Properly sized mixers of the atmospheric type shall be used in all cases, At present.

5.2 The mixer must be installed on top of the existing carburetor or within the existing air cleaner assembly or as approved by the Utility. The existing air cleaner, complete with all temperature sensors and controls, must be retained.

5.3 A suitable gasket shall be used at the base of the natural gas fuel mixer to prevent vacuum leaks.

5.4 The mixer must ensure a proper fuel air ratio at all engine speeds and loads when operating either on gasoline or natural gas.

5.5 Fixed gap (pancake) mixers will not be allowed.

6.0 FUEL LEVEL INDICATOR OPTIONS

6.1 On trucks and/or vans a separate utility approved fuel gauge for natural gas will be acceptable.

6.2 On automobiles, New England instrument integrated fuel gauge, or Utility approved equivalent, will be used with the original equipment gasoline gauge (NGV and gasoline will both register on original equipment gauge as determined by mode of operation).

7.0 GASOLINE LOCK OFF

7.1 A gasoline lock off solenoid valve shall be installed on all vehicles which have a mechanical fuel pump.

7.2 The gasoline shut off solenoid will be located as close to the carburetor as possible between the fuel pump and the carburetor; in a location where premature failure will not occur due to engine heat or salt spray.

7.3 The solenoid valve is to be installed with steel tube connectors and steel tubing on both the upstream and downstream sides.

8.0 ELECTRICAL WIRING HARDWARE AND CONNECTIONS

8.1 All wiring connections shall be soldered. If terminals are used then wire must be soldered to the terminal. All connections are to be secure, tested for integrity, and to be covered with electrical tape or shrink wrap. In specific instances and through consultation with the utility, Packard connectors may be considered.

8.2 A universal or direct replacement dual curve ignition module is to be installed on all vehicles. The universal module is to be installed underneath the dash where possible. If this module must be installed in the engine compartment, then all joints must be coated with silicone to waterproof the box. The module cannot be installed in a location where high engine heat or excessive moisture is present. All dual curve ignition connecting plugs are to be coated with Utility approved insulating material. In the case of direct replacement dual curve ignition modules, the original O.E.M. module must remain intact so that it can be used as a by-pass.

8.3 Landi-Renzo regulators will be fitted with a Bosch waterproof relay on the regulator body under the hood, where required. Alternatively the relay can be mounted remotely inside the vehicle under the dashboard to prevent the corrosion problem.

8.4 All new NGV electrical circuits must be fused adequately with North American style automotive fuses and North American fuse holders such as A.C. Delco part number 094263 or 993081. Underhood fuses must be watertight and energized only when the ignition switch is in the "cranking" and "on" position.

8.5 All new NGV wiring must follow the vehicle contours and be installed in properly sized automotive quality plastic convoluted looming, such as General Motors A.C. Delco Flexgard.

8.6 Dual fuel selector switches are to be of the positive 3-pole or rotary design. The Utility must approve type, location and mounting.

8.7 Colour coded wiring diagrams particular to each model of vehicle conversion must be provided by the conversion centre.

9.0 MISCELLANEOUS

9.1 All emission control devices are to remain intact and operable in the gasoline mode after the conversion.

9.2 The Utilities natural gas vehicle technical data/performance sheet (Appendix I) must be completed at the time of conversion.

9.3 All vehicles will be tested on a chassis dynanometer prior to and after conversion on both gasoline and natural gas modes. All horsepower figures and tune-up specifications will be recorded (on Appendix I) and returned to the Utility unless specified otherwise. Horsepower loss of more than 4% on gasoline mode, after conversion, may not be accepted and must be reported to the utility.

9.4 Manufacturer's bulletins and subsequent revisions of all of the major components, i.e. dual curve ignition, regulator, mixer, fuel gauge, etc. are to be forwarded to the Utility following conversion to natural gas/gasoline.

9.5 Components must be consistent in make, model and manufacturer. Identical vehicles must be converted in an identical fashion with respect to components and location of conversion equipment.

9.6 After conversion and before delivery to the Utility, the natural gas initial spark, timing angle must be stamped on the NGV system information plate located under the hood.

NGV TECHNICAL DATA AND PERFORMANCE SHEET

Date of Installation: ____________________

Installer's Name: ____________________

Conversion Centre Name and Address: ____________________

____

____

Vehicle No.: __________ Make and Model: ____________________

Licence No.: __________ Vehicle Serial No.: ____________________

Mileage: __________ Engine Size: ____________________

NGV Conversion Equipment

Regulator - Make & Model: ____________________

____

Serial No.: ____________________

Mixer - Make & Model: ____________________

	Cylinder Manufacturer	Size	Serial No.	Test Date
(1)				
(2)				
(3)				
(4)				
(5)				
(6)				

Location of Fill Block: ____________________

Dual Curve - Make and Model: ____________________

Serial No.: ____________________

Initial Timing on:

Gasoline _____ Degrees at _____ RPM (idle) with no vacuum advance.

Natural Gas _____ Degrees at _____ RPM (idle with no vacuum advance.

Emission and Horsepower Tests

	HC ppm (idle)	HC ppm (cruise)**	CO% (idle)	CO% (cruise)**	RHP*
Gasoline Before Conversion					
Gasoline After Conversion					
Natural Gas					

* RHP is measured at 80 km/hour one gear below drive at wide open throttle.

** 11 - 12 inches of vacuum.

____
Signature of Dyno Operator

NOTE: IF ANY OF THE ABOVE INFORMATION IS FOUND TO BE INCORRECT OR FALSE, PAYMENT WILL BE WITHHELD.